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OMEGA ENGINEERING, INC.

An OMEGA Group Company

Model 650/660

Microprocessor Controlled Temperature Indicator

Operator's Manual

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OMEGA warrants this unit to be free of defects in materials and workmanship and to give satisfactory service for a period of 13 months from date of purchase. OMEGA Warranty adds an additional one (1) month grace period to the normal one (1) year product warranty to cover handling and shipping time. This ensures that our customers receive maximum coverage on each product. If the unit should malfunction, it must be returned to the factory for evaluation. Our Customer Service Department will issue an Authorized Return (AR) number immediately upon phone or written request. Upon examination by OMEGA, if the unit is found to be defective it will be repaired or replaced at no charge. However, this WARRANTY is VOID if the unit shows evidence of having been tampered with or shows evidence of being damaged as a result of excessive current, heat, moisture, vibration, or misuse. Components which wear or which are damaged by misuse are not warranted. These include contact points, fuses, and triacs.

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To avoid processing delays, also please be sure to include:

1. Returnee's name, address, and phone number.
2. Model and Serial numbers.
3. Repair instructions.

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1. Introduction 1-1

1.1 General Description 1-1
1.2 Quick Hook-up Guide 1-2

2. Specifications 2-1

2.1 Thermocouple Inputs 2-1
2.2 Digital Outputs 2-2
2.3 Analog Output (Optional) 2-3
2.4 Accuracy 2-4
2.5 Analog to Digital Conversion 2-5
2.6 Power 2-5
2.7 Display 2-5
2.8 Environmental 2-6
2.9 Dimensions 2-6
2.10 Reliability 2-6

3. Theory of Operation 3-1

3.1 General Thermocouple Operation 3-1
3.2 Cold Junction Compensation & Linearization 3-4
3.3 System Operation 3-6
3.3.1 Input Signal Conditioning & Self Calibration 3-7
3.3.2 Analog to Digital Conversion 3-8
3.3.3 Display 3-10
3.3.4 Digital Output Format 3-10
3.3.5 Analog Output (Optional) 3-16
3.3.6 Power Supply 3-17

4. Installation, Applications & Set-up Procedures 4-1

4.1 General 4-1
4.2 Shipping Configuration 4-1
4.3 Mounting 4-1
4.4 Connecting Thermocouples 4-3
4.4.1 Thermocouple Applications 4-5
4.5 Connecting the ASCII Digital Output 4-7
4.5.1 ASCII Character Serial Application 4-9
4.5.2 Serial Output Applications 4-11
4.6 Connecting Power 4-14
4.7 Connecting Analog Output 4-14
4.7.1 Analog Output Applications 4-15
4.8 °C/°F Selection 4-17
4.9 Model 660 Thermocouple Programming 4-18

5.1 General 5-1
5.2 Calibration Set Up 5-2
5.3 Calibration Procedure 5-3

6. Service Information 6-1

7. Appendix I Schematics (Model 650) 7-1
Appendix II Schematics (Model 660) 7-4

1. Introduction 1-1

1.1 General Description 1-1
1.2 Quick Hook-up Guide 1-2

2. Specifications 2-1

2.1 Thermocouple Inputs 2-1
2.2 Digital Outputs 2-2
2.3 Analog Output (Optional) 2-3
2.4 Accuracy 2-4
2.5 Analog to Digital Conversion 2-5
2.6 Power 2-5
2.7 Display 2-5
2.8 Environmental 2-6
2.9 Dimensions 2-6
2.10 Reliability 2-6

3. Theory of Operation 3-1

3.1 General Thermocouple Operation 3-1
3.2 Cold Junction Compensation & Linearization 3-4
3.3 System Operation 3-6
3.3.1 Input Signal Conditioning & Self Calibration 3-7
3.3.2 Analog to Digital Conversion 3-8
3.3.3 Display 3-10
3.3.4 Digital Output Format 3-10
3.3.5 Analog Output (Optional) 3-16
3.3.6 Power Supply 3-17

4. Installation, Applications & Set-up Procedures 4-1

4.1 General 4-1
4.2 Shipping Configuration 4-1
4.3 Mounting 4-1
4.4 Connecting Thermocouples 4-3
4.4.1 Thermocouple Applications 4-5
4.5 Connecting the ASCII Digital Output 4-7
4.5.1 ASCII Character Serial Application 4-9
4.5.2 Serial Output Applications 4-11
4.6 Connecting Power 4-14
4.7 Connecting Analog Output 4-14
4.7.1 Analog Output Applications 4-15
4.8 °C/°F Selection 4-17
4.9 Model 660 Thermocouple Programming 4-18

5.1 General 5-1
5.2 Calibration Set Up 5-2
5.3 Calibration Procedure 5-3

6. Service Information 6-1

7. Appendix I Schematics (Model 650) 7-1
Appendix II Schematics (Model 660) 7-4

1.1 GENERAL DESCRIPTION

The Model 650/660 Series are high performance single channel thermocouple meters that can measure temperature accurately between −245 and +1999 in degrees Celsius or Fahrenheit. These meters are capable of interfacing with six separate thermocouple types which include J, K, T, E, S and R. Thermocouple selection is factory programmed for the Model 650 or user selectable by purchasing the universal Model 660. Thermocouple linearization, cold-junction compensation, gain and offset error correction and °C/°F scaling are automatically performed via firmware internal to the microprocessor.

A linearized digital output is provided in ASCII character serial format for easy interface to printers, terminals and other standard peripherals. For remote data acquisition applications, an optional isolated 20mA serial loop and TTL compatible (Non-Isolated) interface are available. An optional linearized 1mV/degree analog output can also be provided for easy interface with recorders and other analog instruments. Power can be selected from any one of three versions: 120Vac, 240Vac, or +7.5 to +15Vdc. Input over voltage protection is provided for 300V peak (thermocouple to AC line shorts) and for common mode voltages as high as 1400V peak (AC version). These meters are supplied in a rugged high impact plastic case that meets DIN/NEMA standard dimensions. (See the following sections for more detailed information on specifications, operation, and implementation.)

> WARNING: Be sure power is not applied to the cord when attaching the line voltage wires to unit. Do not plug in until the installation is complete.

1.2 QUICK HOOK-UP GUIDE

1. Determine if you received the proper features with your thermocouple meter by checking the identification label on top of the meter:
   a. Thermocouple Type: J, K, T, E, S or R (Model 650)
      Universal (Model 660)
   b. Power Option: 120Vac, 240Vac, +7.5 to + 28V dc
   c. Analog Output (Optional)
   d. Model 660 Universal Thermocouple Meter
      (Initially set up for J thermocouple type & °C)
   e. Serial Data Output (Option S2)
2. Locate the proper terminals and connector on the rear panel of the meter. (See Figure 1.1 for details)
   a. Power Input Terminals "HI" and "LO"
   b. Thermocouple (T.C.) Terminals "+" and "–"
   c. Analog Output Terminals "+" and "–"
   d. J1, Digital ASCII Output

Connections To Be Made:

1. Connect the thermocouple to the T.C. "+" and "–" inputs (See the note below for grounding considerations.)
   For ANSI standard T.C.'s, the RED wire is connected to (–).

2. Without power connected to the power source connect the power leads to the "HI" and "LO" POWER INPUT terminals. (See the note below for grounding considerations.)

3. Connect the optional analog output "+" and "–" terminals to the instrument of choice. (See the note below for grounding considerations.)

NOTE: Instrument grounding can be accomplished using several approaches. One of the following techniques must be implemented in order to minimize ground loops and maintain system accuracy.

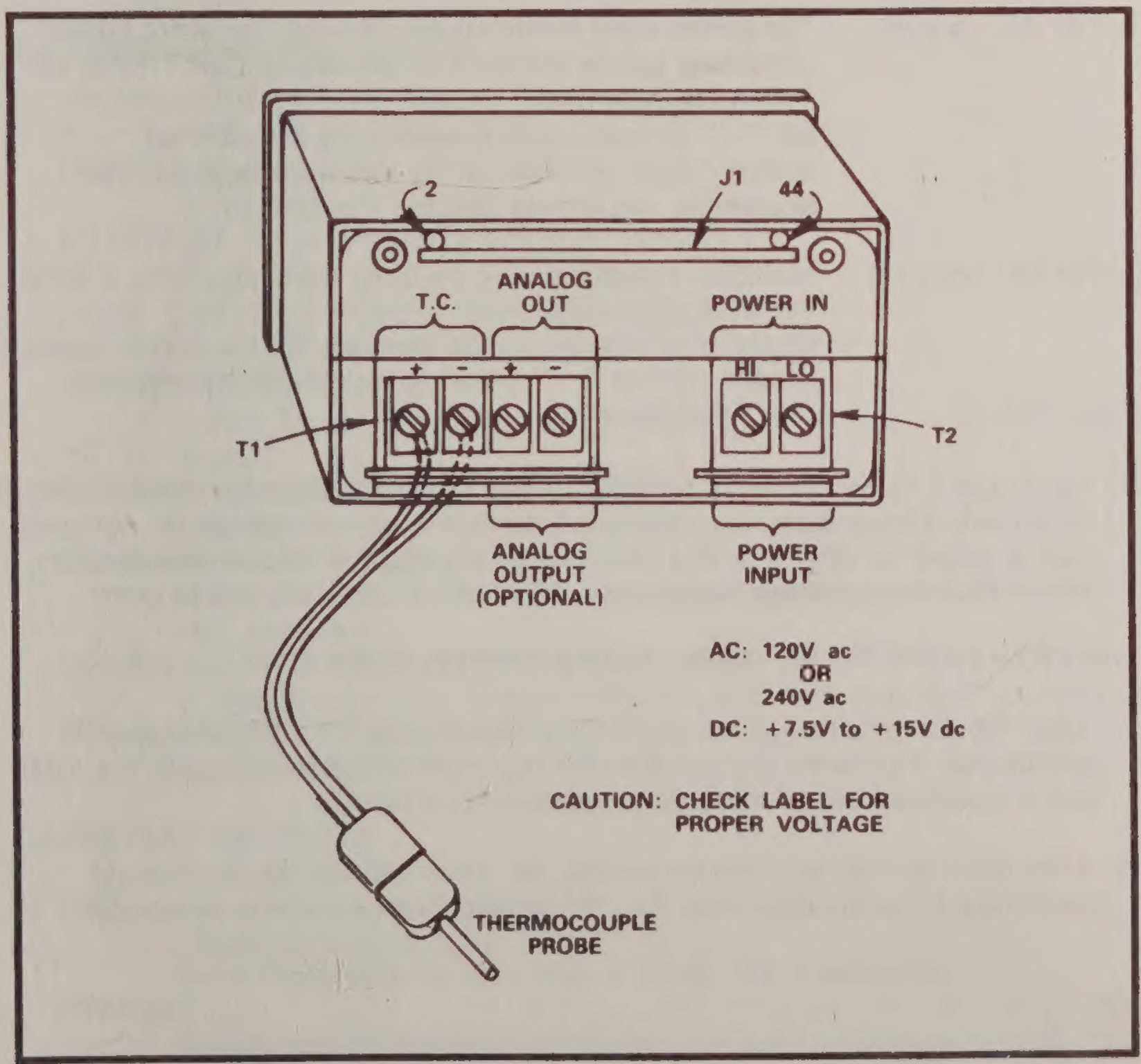


Figure 1.1 Rear Panel View

1. For AC versions: The power input terminals are isolated, therefore proper grounding can be achieved by grounding ONLY ONE OF THE FOLLOWING:
(a) " – " thermocouple terminal, (b) the optional " – " analog output terminal, or (c) the digital ground. The instrument can remain floating if desired.

2. For DC versions: Maintain a single ground point by grounding ONLY ONE OF THE FOLLOWING:
(a) the " – " thermocouple terminal, (b) the digital output ground, (c) the " – " power input, or (d) the optional " – " analog output.

3. The Model 650/660 Series is designed so that only one ground may be connected to the unit. If you must use a grounded thermocouple, do not use the optional analog output to drive a device whose input is grounded. Measurement errors and possible unit damage could occur if this condition is allowed to exist.

OBSERVATIONS TO BE MADE AFTER POWER TURN-ON

1. After the power is turned on, the display should read " + 1888" for approximately 3 seconds. During this time the meter is initialized, calibrates itself, and a functional test of all display segments is performed.

2. After the 3 second initialization period, the meter will display an accurate temperature reading (assuming that the proper thermocouple is connected).

2.1 THERMOCOUPLE INPUTS

THERMOCOUPLE TYPES:
J, K, T, E, S and R
INPUT IMPEDANCE:
> 100MΩ
EXTERNAL (LEAD) RESISTANCE EFFECT:
< 20μV per 350Ω of Lead resistance
COLD JUNCTION COMPENSATION ERROR:
±0.5°C max. ambient temperature (10 to +40°C)
OPEN THERMOCOUPLE:
+EEE Display; +EEEE ASCII DIGITAL OUTPUT; +2.048V analog output
THERMOCOUPLE SHORT TO AC LINE:
Internal Protection Provided to 300V peak, (200Vac RMS)
COMMON MODE VOLTAGE:
1400V peak (DC or AC), Between Input and Power Line Ground (AC Versions)
COMMON MODE REJECTION RATIO:
> 130dB with 250Ω Source Imbalance (AC Versions) (DC to 60Hz)
NORMAL MODE REJECTION RATIO:
> 80dB @50/60Hz

2.2 DIGITAL OUTPUTS

DATA:
Character Serial ASCII
Drive Capability: 2TTL Loads, CMOS/TTL Compatible
STROBE:
Negative transition determines when character serial data is valid.
CMOS/TTL compatible.

2

SPECIFICATIONS

DIGITAL OUTPUTS (cont.)

OVERRANGE:
±EEEE

CHARACTER RATE:
Selectable on J1 (pin 32)
Grounded: 25 characters/sec. (slow)
Open: 100 characters/sec. (fast)

MINIMUM TIME BETWEEN NEW DATA UPDATE:
150ms

ISOLATED SERIAL OUTPUT (Optional)

DATA:
Asynchronous ASCII 20mA Current Loop
(Optically Isolated to ±600V peak)

BAUD RATE:
Selectable on P1 (Pin 32)
Grounded: 300 Baud (SLOW)
Open: 1200 Baud (FAST)

DISTANCE:
10,000 ft. max

SERIAL OUTPUT (Nonisolated, Optional)

DATA:
Serial ASCII

DRIVE CAPABILITY:
2TTL Loads, CMOS/TTL Compatible

BAUD RATE:
(Same as Isolated Serial Output)

OVERRANGE:
±EEE.E

MINIMUM TIME BETWEEN NEW DATA UPDATE:
150ms

DIGITAL INPUTS

$\overline{\text{REQ}}$: LOW-LEVEL TRIGGERED: (Pin 20 on J1)

Must go low at any time other than during data transmission to be recognized. $\overline{\text{REQ}}$ line taken low during data transmission will not be acknowledged and the ASCII digital output transmission will not occur. Display readings are not effected by $\overline{\text{REQ}}$.

CHARACTER RATE: (Pin 32 on J1)

Grounded: 25 characters/sec. (SLOW)
Open: 100 characters/sec. (FAST)

$\overline{\text{SERIAL INPUT}}$: (OPTIONAL): EDGE TRIGGERED, CURRENT ON TO CURRENT OFF

Must be triggered at any time other than during data transmission to be recognized. Serial Input triggered during data transmission will not be acknowledged and the 20mA isolated/TTL compatible serial output transmission will not occur. Display readings are not affected by $\overline{\text{Serial Input}}$.

2.3 ANALOG OUTPUT (OPTIONAL)

VOLTAGE:

1mV/degree, Fahrenheit or Celsius linearized

CURRENT:

±2mA max. drive

CMV:

1400V peak
(AC or DC) Peak Between Analog Output Ground and AC Power Line Ground

OVERRANGE:

+2.048V, −0.512V

ANALOG OUTPUT (cont.)

ACCURACY:
± 2mV From Display Reading
DIFFERENTIAL NONLINEARITY:
± 1mV

2.4 ACCURACY

TEMPERATURE RESOLUTION:
1 °C/1 °F
RANGE TEMPERATURE COEFFICIENT:
± 25ppm/ °C typ., ± 60ppm/ °C max.
All Ranges Are Guaranteed Monotonic.

SENSOR

TYPE	RANGE	READOUT ACCURACY @ 25°C[1]	
J	−165° to 760 °C	± 0.7 °C	± ½ LSD
J	−265° to 1400 °F	± 1.3 °F	± ½ LSD
K	−50° to 1250 °C	± 0.9 °C	± ½ LSD
K	−58 °to 1999 °F	± 1.6 °F	½ LSD
T	−150° to 400 °C	± 0.8 °C	± ½ LSD
T	−238° to 752 °F	± 1.4 °F	± ½ LSD
E	−100° to 870 °C	± 1.0 °C	± ½ LSD
E	−148° to 1598 °F	± 2.0 °F	± ½ LSD
S, R	+300° to 1760 °C	± 1.5 °C	± ½ LSD
	0° to 299 °C	± 6.0 °C	± ½ LSD
S, R	+572° to 1999 °F	± 3.0 °F	± ½ LSD
	+32° to 571 °F	± 12.0 °F	± ½ LSD

[1]Readout Accuracy Includes All Conformity Errors, CJC Errors, Gain Errors and Offset Errors.

2.5 ANALOG TO DIGITAL CONVERSION

TECHNIQUE:
Offset Dual Slope With Gain And Offset Error Correction
RATE:
2.5 Conversions/Second (Typical)
INPUT INTEGRATION PERIOD:
100 Milliseconds for 50/60Hz Noise Rejection

2.6 POWER REQUIREMENTS (Choice of Three Supply Ranges)

AC:
90Vac to 132Vac @ 25mA (47 to 500Hz)
198Vac to 264Vac @ 12.5mA (47 to 500Hz)
DC:
+7.5V to + 28V dc @ 200mA (Protected Against Supply Reversals)

2.7 DISPLAY

TYPE:
Seven Segment Orange LED 0.56" (14.3mm) high
POLARITY INDICATION:
"+" or "−" displayed
OVERRANGE INDICATION
± EEE
DISPLAY TEST:
At Power Turn-On, 3 Second Display Of "+1888" Tests All Segments Of Display

2.8 ENVIRONMENTAL

RATED TEMPERATURE RANGE:
+10°C to +40°C

OPERATING TEMPERATURE RANGE:
−10°C to +50°C

STORAGE TEMPERATURE RANGE:
−40°C to +85°C

RELATIVE HUMIDITY:
0 to 90%, non condensing

2.9 DIMENSIONS

CASE:
3.78″ x 1.89″ x 5.13″ (96.8mm x 48.9mm x 131.3mm), high impact molded plastic case. DIN/NEMA Standard

Panel Cut Out: $3.622''^{+.031''}_{-\ 000''}$ $(92^{+\ .8}_{-\ \ 0})$mm x $1.771^{+.024''}_{-\ 000''}$ $(45^{+.6}_{-\ 0})$mm

PANEL THICKNESS:
1/16″ (1.5mm) to 3/16″ (4.8mm)

WEIGHT:
15.2 oz. (431 grams) max., AC powered
12.0 oz. (341 grams) max., DC powered

2.10 RELIABILITY

MTBF:
>59,000 hours calculated

BURN IN:
168 Hours at +50°C and Power On/Off Cycles

CALIBRATION:
NBS Traceable

RECALIBRATION:
Recommended 15 - Month Intervals

WARRANTY:
12 months

3.1 GENERAL THERMOCOUPLE OPERATION

A thermocouple is a device that measuress temperature by converting thermal energy to electrical energy. In order for this conversion to take place, two phenomena must occur: (1) Two dissimilar metals must be bound together at one end to form the "HOT" or measuring junction with the free end attached to the instrument constituting the "COLD" or reference junction (Shown in Figure 3.1) and (2) the "HOT" and "COLD" junction must be maintained at different temperatures (ΔT). The magnitude of voltage (V_1) developed at the "COLD" junction is directly proportional to temperature differential (ΔT) developed between the two junctions. The relation between ΔT and V_1 is usually not linear.

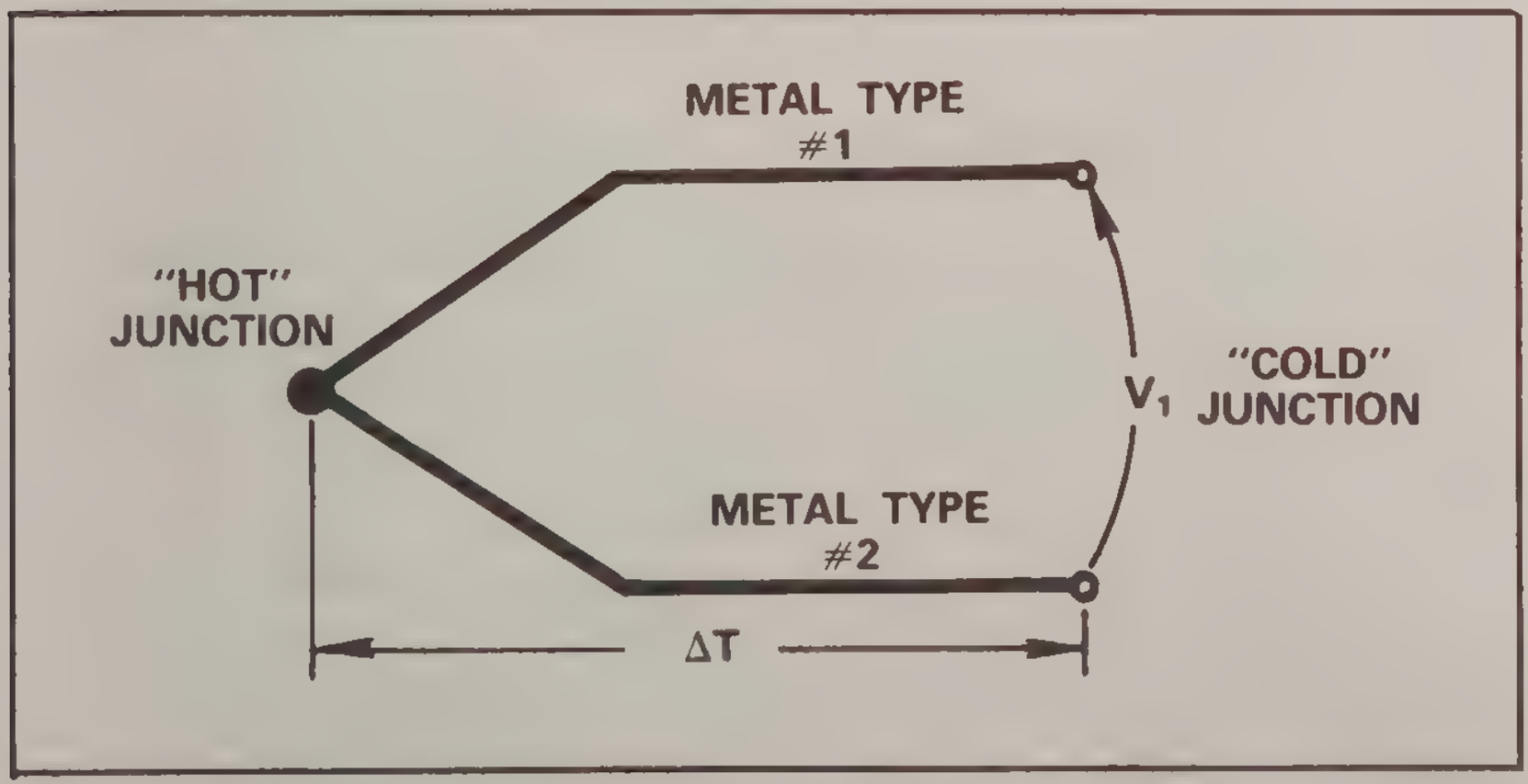


Figure 3.1. Typical Thermocouple

In order for an accurate temperature measurement to be made of the "HOT" junction point, the "COLD" junction temperature must be known. Currently, there are two approaches in which this can be accomplished:

1) By setting the "COLD" junction temperature to a fixed value, or (2) By measuring the ambient temperature at the "COLD" junction termination.

One common convention for setting the "COLD" junction temperature to a fixed value is to place that junction into an ice bath which is set at the melting temperature of ice, 32°F/0°C.

The Model 650/660 Series uses the second approach. By physically placing a "COLD" junction temperature sensor near the thermocouple input terminal block, the most accurate measurement of the ambient "COLD" junction temperature is made.

MODEL 650/660 SERIES THERMOCOUPLE TYPE

Thermocouples come in many forms depending upon the two dissimilar metals used, temperature range, and the application required. Because any two dissimilar metals that are bonded together can theoretically form a thermocouple, the National Bureau of Standards (NBS) sets standards and establishes calibration tables for each thermocouple temperature vs. output voltage. Shown in TABLE 3.1 are the thermocouple types, metallic composition, and environmental applications that can be interfaced with the model 650/660 series.

Each thermocouple type is designated by an alphabetic letter that is accepted by the American National Standards Institute (ANSI). Shown in Figure 3.2 are the thermocouple types, that can interface with the Model 650/660 Series, displaying each NBS calibrated range and the corresponding specified operating range of the meter.

Since more than one thermocouple is available for a specific temperature range, refer to the Omega Temperature Measurement Handbook or contact Omega Engineering at (203) 359-1660 for assistance.

ANSI DESIGNATED THERMOCOUPLE TYPE	METALLIC COMPOSITION	ENVIRONMENTAL APPLICATIONS
E	Chromel-Constantan	Vacuum or inert, mildly oxidizing or reducing atmosphere. Not subject to corrosion at sub-zero temperatures.
J	Iron-Constantan	Reducing atmospheres
K	Chromel-Alumel	Clean Oxidizing Atmosphere
S	Platinum-Platinum 10% Rhodium	High resistance to oxidation and corrosion.
T	Copper-Constantan	Mildly oxidizing and reducing atmospheres where moisture is present; low temperatures up to +750°F.
R	Platinum-Platinum 13% Rhodium	High resistance to oxidation and corrosion.

TABLE 3.1 - Thermocouple Types, Metallic Composition, and Environmental Applications

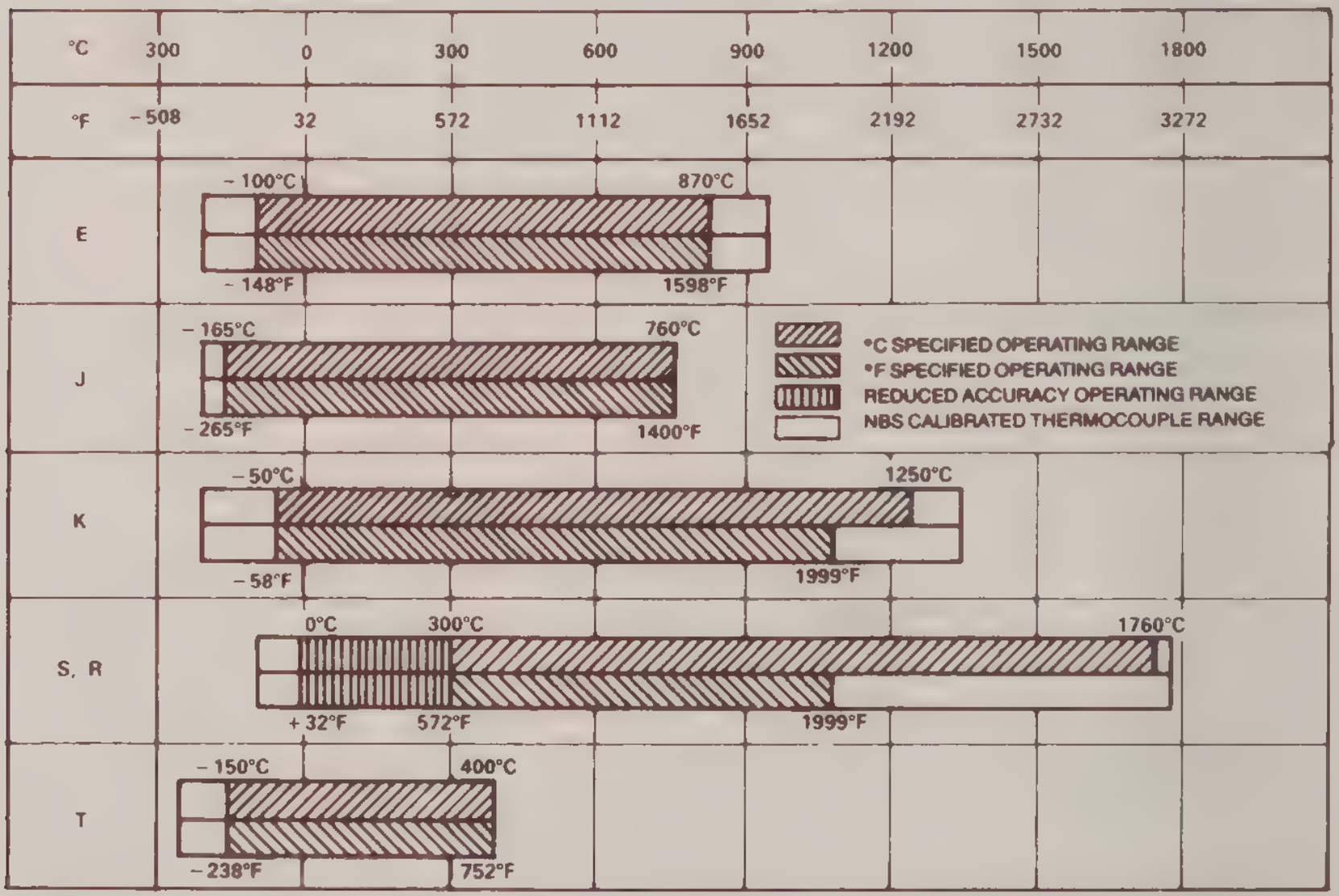


Figure 3.2. Thermocouple Temperature Range & Model 650/660 Specified Operating Ranges

3.2 COLD JUNCTION COMPENSATION AND LINEARIZATION

Cold junction compensation is provided by measuring the temperature of the thermocouple screw terminals. (See Section 3.1.) The Model 650/660 places an accurate temperature sensor in the terminal block to obtain the best possible

[illegible] The [illegible] temperature is measured periodically and [illegible] a memory. The microprocessor uses the information to mathematically [illegible] the thermocouple at 0°C before linearization is performed. Thermocouple linearization, for the Model 570 and 571, is accomplished in firmware using the multisegment piecewise linear approximation technique. Here, the thermocouple [illegible] broken up into [illegible] segments. The linearization values are [illegible] stored in memory to provide the best overall error of system conformity. See Figure 3.3. The multisegment formula is [illegible] in ROM-like form and used for each thermocouple measurement. Since linearization is provided digitally, all [illegible] errors due to time and temperature are eliminated.

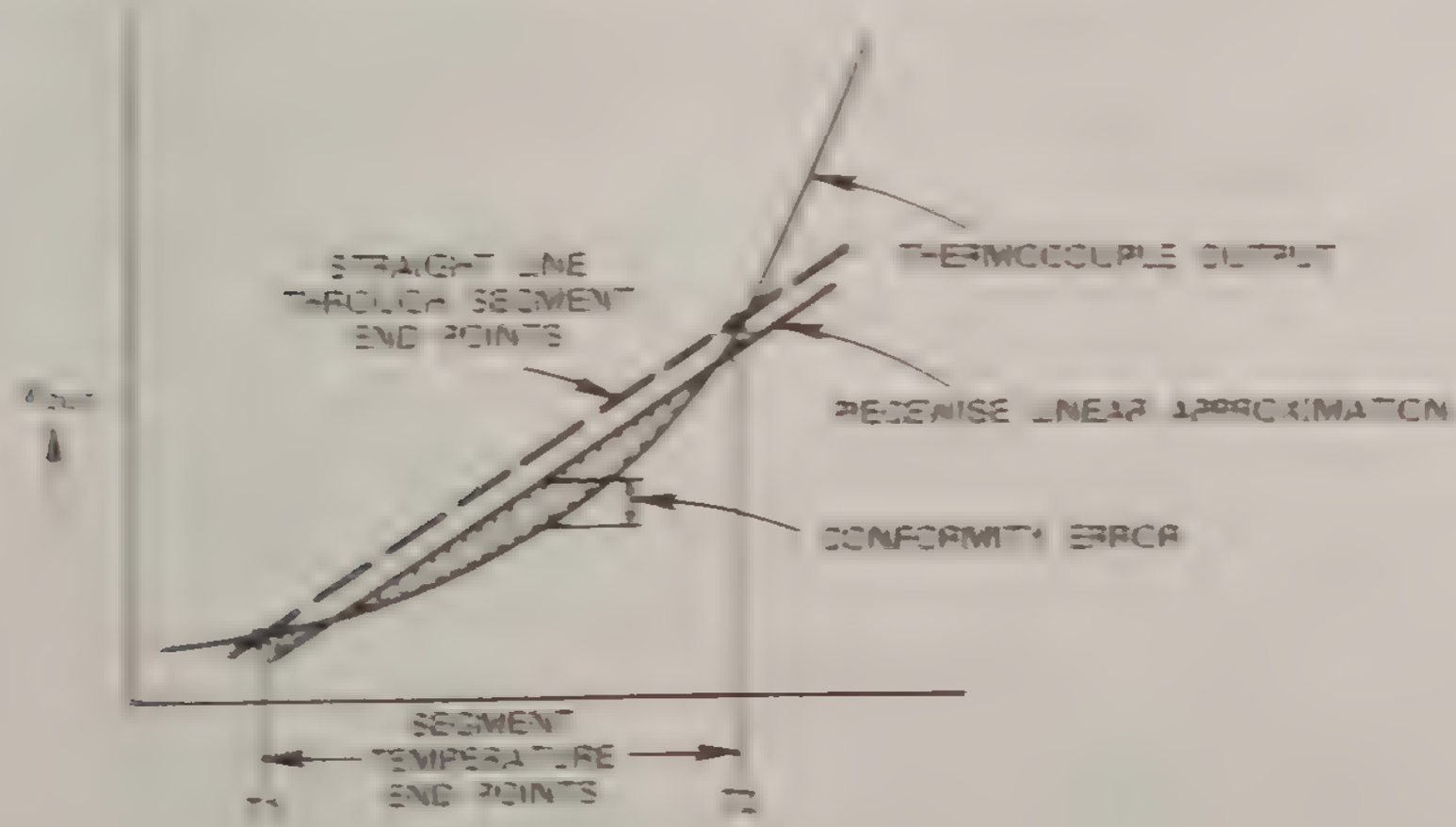


Figure 3.3. Linearization and Conformity Error

3.3 SYSTEM OPERATION

The functional block diagram for the Model 650/660 Series is shown in Figure 3.4. The microprocessor automatically compensates for all offset errors, gain errors, cold junction compensation and performs thermocouple linearization. Analog to digital conversion, display and the ASCII digital output are also under microprocessor control.

There are six sections in the Model 650/660 Series Thermocouple Meter:

1. Input Signal Conditioning and Self-Calibration
2. Analog-to-Digital Conversion
3. Display
4. ASCII Digital Outputs
   A. Character Serial
   B. Isolated 20mA Loop (Optional)/TTL Serial Interface
5. Analog Output (optional)
6. Power Supply

Each of these sections is described briefly in the following paragraphs. For detailed circuit information, refer to the schematic in Appendix 1.

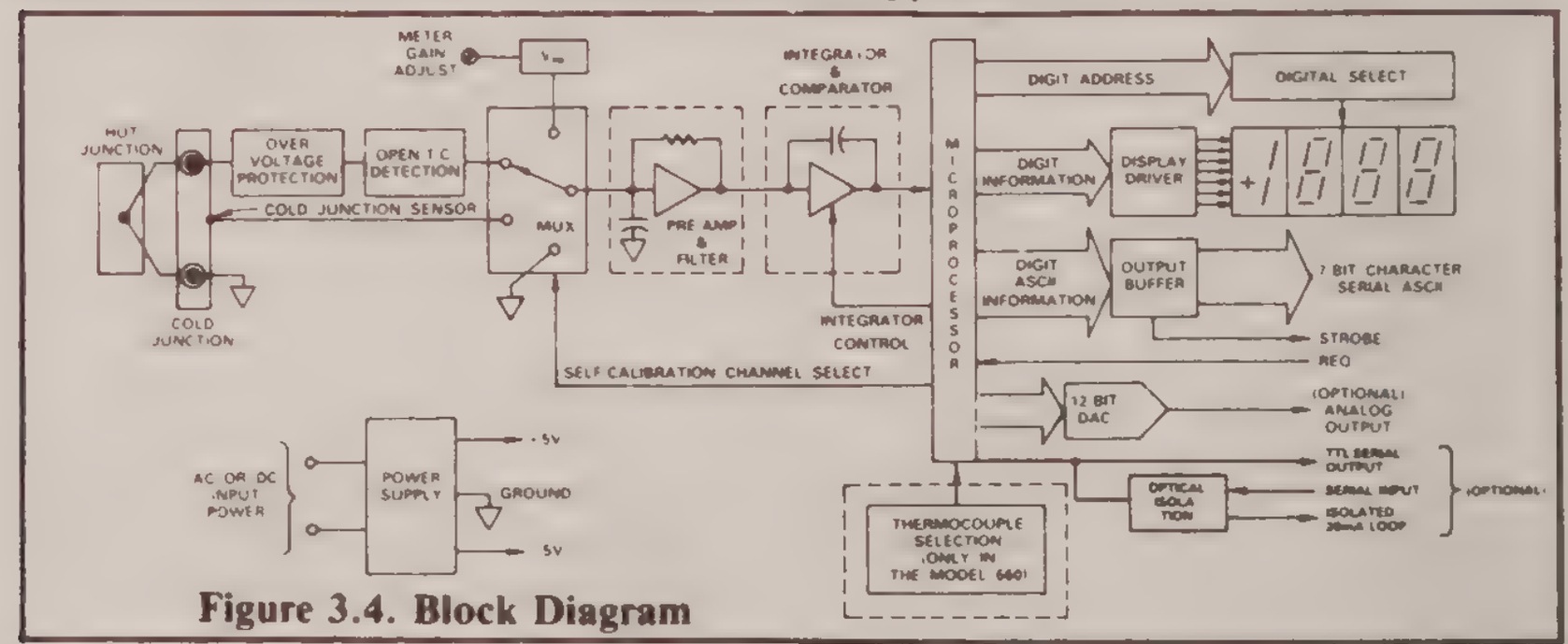


Figure 3.4. Block Diagram

3.3.1 INPUT SIGNAL CONDITIONING AND SELF CALIBRATION

Input signal conditioning begins with over-voltage protection and open-thermocouple detection circuitry. The over-voltage protection protects the meters input against signals as high as 300V peak before breakdown occurs. Open-thermocouple detection is provided so the user can readily determine if an open circuit occurs between the "HOT" junction of the thermocouple and "COLD" junction point of the meter.

Thermocouple input signal conditioning and self-calibration are performed by switching the multiplexer between system ground, a stable voltage reference, the cold junction compensation, and the protected thermocouple input terminal shown in Figure 3.5. In normal operation, the protected thermocouple input is measured continually with each of the other three positions sampled periodically to update the self-calibration constants stored in memory. The microprocessor then uses this information to perform self-calibration and scaling on each thermocouple measurement.

Following the multiplexer is a pre-amplifier which provides both signal gain and filtering which scales the input and minimizes noise related inaccuracies.

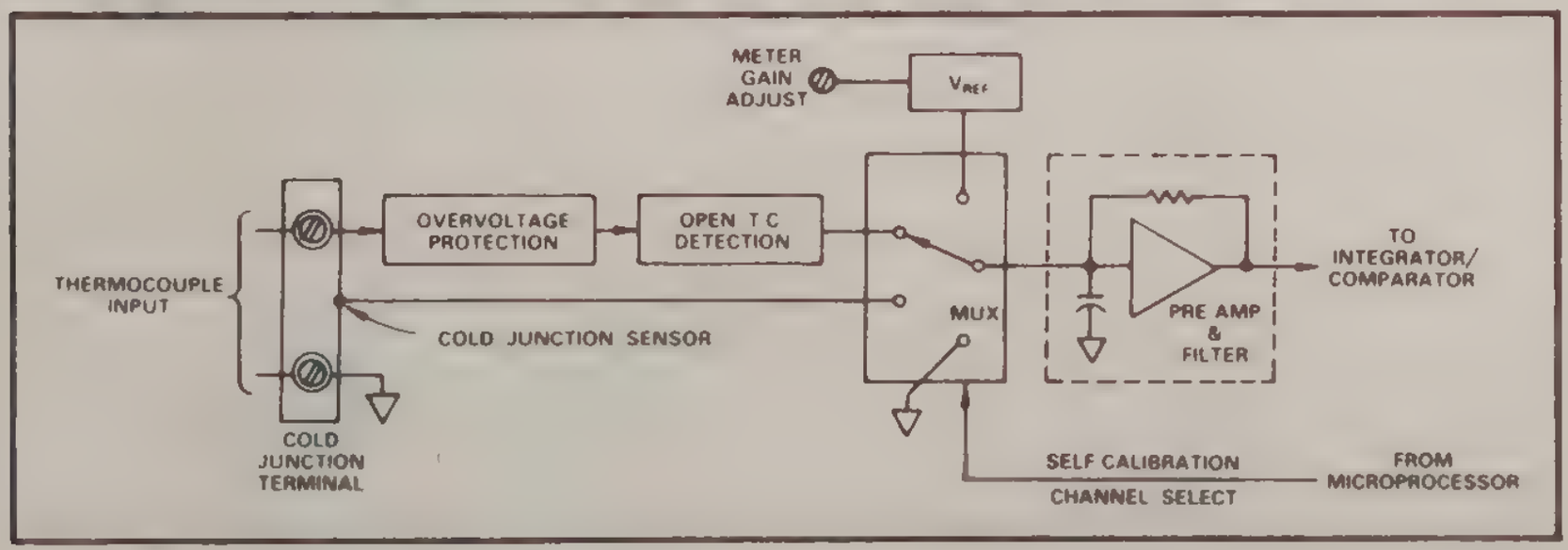


Figure 3.5. Input Signal Conditioning and Self-Calibration

3.3.2 ANALOG TO DIGITAL CONVERSION

The analog to digital converter uses the offset dual-slope integration technique. The analog to digital conversion is implemented by the integrator/comparator and the microprocessor as shown in Figure 3.6. In this dual-slope process, the integrate/deintegrate periods are performed by the integrator/comparator with all timing and counting functions being under microprocessor control.

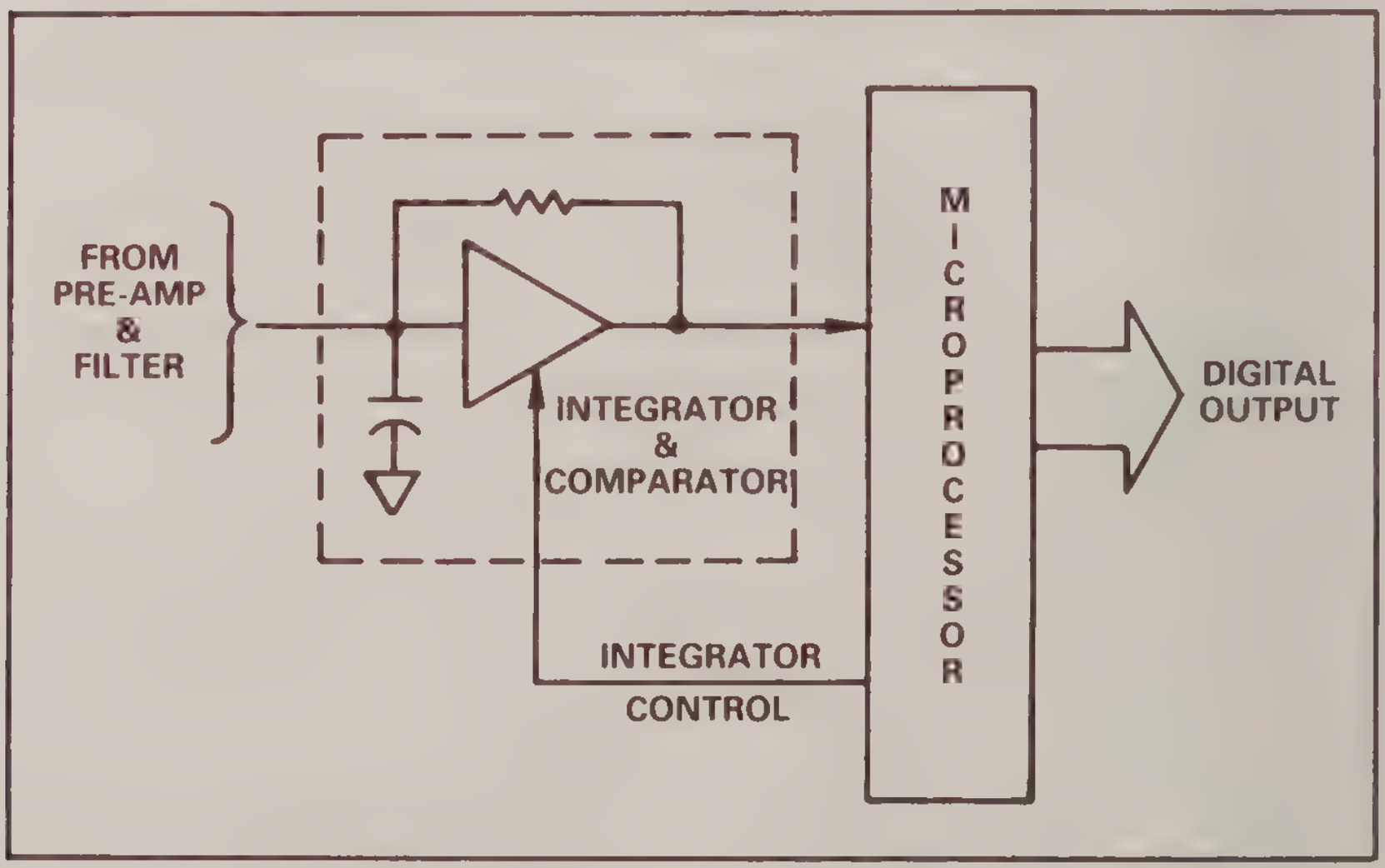


Figure 3.6. A/D Converter

The nominal integrate period is set exactly at 100msec during which time the integrators capacitor charges at a rate proportional to the conditioned input signal. After the precise 100msec period, the microprocessor places the converter in the deintegrate mode. The integrators capacitor is discharged at a fixed rate that is counted by the microprocessor until the comparator threshold is reached. At the time the threshold is reached, the value counted by the microprocessor will be proportional to the magnitude of the conditioned input signal.

Because the integration period is 100msec, 50Hz and 60Hz normal mode noise is inherently rejected.

Since the maximum count that the Model 650/660 Series can reach is ± 1999, any signal exceeding this counted value or the thermocouple limits will cause an overrange condition to be displayed as ± EEE on the front panel display and ± EEEE at the ASCII digital output.

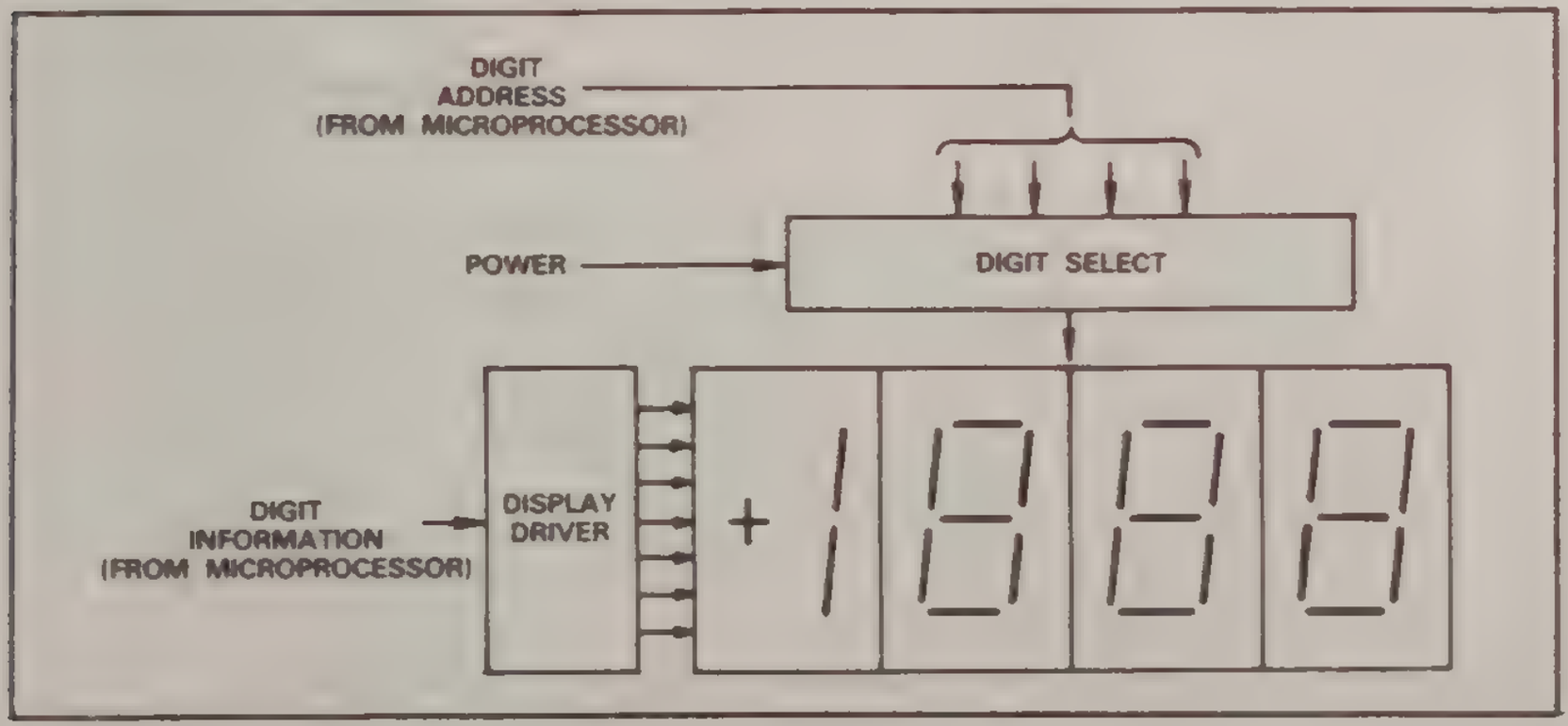


Figure 3.7 Display Block Diagram

3.3.3 DISPLAY

Shown in Figure 3.7 is the block diagram for the display function. The inputs required for operation include the seven segment digit information, four bit digit address, and +5Vdc internal power. All digit address and digit information is provided sequentially to the display by the microprocessor.

3.3.4 DIGITAL OUTPUT FORMAT

Character-Serial ASCII vs. Parallel BCD

Parallel BCD, although still used in some digital applications, has several drawbacks in attempting to interface to most peripheral equipment being used today. The first, obviously, is the number of data lines required to transmit the digital temperature data. Next, it is very difficult and expensive to convert parallel BCD to a character serial format, which, as was previously mentioned, is compatible with most peripherals. Also, parallel BCD provides only numerical information; it does not provide polarity or °C/°F indication, nor does it provide any form of communications protocol.

The Model 650/660 on the other hand provides digital temperature data in a standard, 7-bit character serial ASCII format; polarity, °C/°F indication and communications protocol, including a strobe pulse, REQUEST (REQ) line and a character/baud rate control, as shown in Figure 3.4 are also provided.

The output data is always sent in a burst of 9 characters, as follows:

Character	1	2	3	4	5	6	7	8	9
	+	1	9	9	9	(SP)	F	(CR)	(LF)

Character 1: Polarity sign, either + or −

Characters 2-5: Numerical data as shown on the front panel display

Character 6:	ASCII code for "space"
Character 7:	Temperature scale, either C or F
Characters 8-9:	Carriage return and line feed. These are standard ASCII line terminators.

ASCII Digital Output:
The digital output lines (Data 1-7) are brought out to the edge connector at the rear of the meter. Data 1 is the LSB. Positive logic is used; a "High" output line corresponds to an ASCII "1". The character data lines are accompanied by a STROBE signal which indicates when the character data is valid. The character data is valid when STROBE goes low and remains valid as long as STROBE is low.

The digital output message is initiated when the REQ line is held low; the meter will output a digital sequence at the end of every conversion cycle. The REQ signal is cleared during a character output sequence and requests for data at this time will be ignored.

The REQ line is filtered for noise rejection and a low-going, minimum pulse width of 2μs is required to insure valid output data.

The STROBE signal is buffered by CMOS buffers for better noise immunity when driving long output cables. The STROBE signal is located on the output edge connector next to GND. The ground wire shields the strobe from the data lines when ribbon cable is used. This helps prevent crosstalk from the data lines to STROBE. Using ribbon cable in this manner, reliable transmission up to 10 feet can be expected. For longer cables or cables with bundled wiring, using twisted pair on the STROBE line is recommended. Cables longer than 10 feet should be approached with caution to avoid crosstalk and noise on the REQ line.

The digital output data can be transmitted in two character rates controlled by CHARACTER/BAUD RATE input line (pin 32). If pin 32 is left open or held high, (logic "1") the characters are sent at 100 characters a second. Tying pin 32 low (logic "0") changes the rate to 25 characters/second which may be necessary for slower input devices. The CHARACTER/BAUD RATE line is sampled by the μP before a character burst so that it is impossible for the character rate to change while a digital output is in progress.

Figure 3.8 and Table 3.2 are the timing diagram and logic chart, respectively, for the Model 650/660.

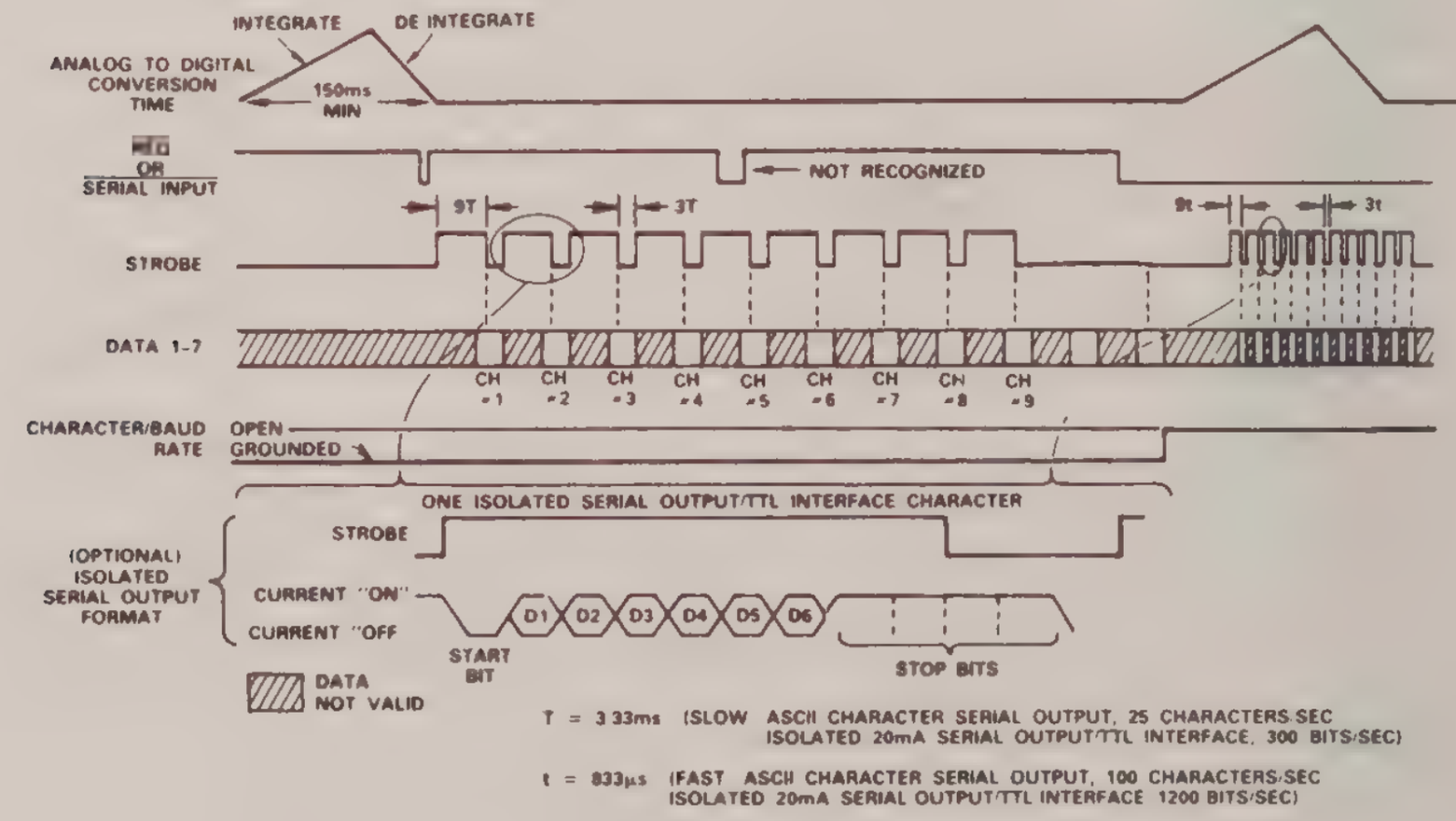
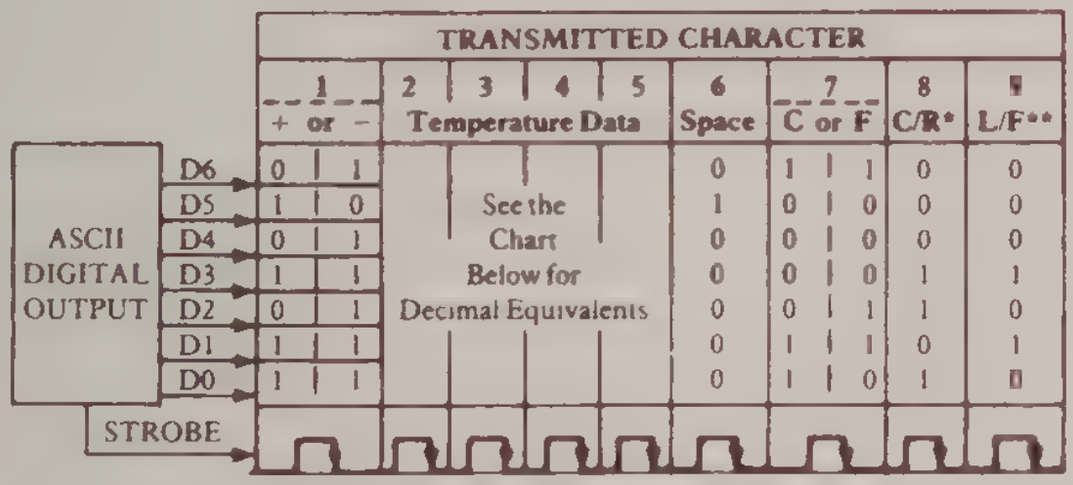


Figure 3.8 650/660 Timing Diagram

Table 3.2 Model 650/660 Logic Chart



ASCII Character Serial Data is Valid on the Falling Edge of the Strobe Pulse.

Temp. Data Decimal No.	ASCII Data for Characters 2, 3, 4 & 5						
	D6	D5	D4	D3	D2	D1	D0
0	0	1	1	0	0	0	0
1	0	1	1	0	0	0	1
2	0	1	1	0	0	1	0
3	0	1	1	0	0	1	1
4	0	1	1	0	1	0	0
5	0	1	1	0	1	0	1
6	0	1	1	0	1	1	0
7	0	1	1	0	1	1	1
8	0	1	1	1	0	0	0
9	0	1	1	1	0	0	1
E	1	0	1	0	0	0	1

NOTE: *C/R = Carriage Return **L/F = Line Feed

Serial Output:
The isolated serial output provides data in standard bit serial asynchronous ASCII format. This feature allows communication to serial devices with only two or four interconnecting wires. The serial output is an opto-isolated current switch capable of handling 20mA of loop current with common mode voltages up to 600 volts. Loop current power and current limiting must be provided by the user. The current switch is on during idle periods and to signify a logical "1". The switch is off for logical "0". In most applications, interfacing the loop to peripheral devices can be accomplished with a single resistor. Since the switch is isolated, it can be arranged to either source or sink a resistor load. Various examples of interfacing the serial output of the Model 650/660 are shown in Figure 3.9. (The switch has a saturation voltage of 1.2V max at 20mA).

The serial interface of the Model 650/660 also includes an isolated data request line (SERIAL INPUT). This input is edge sensitive: a transition from current on to current off is recognized as a request for data. The current in the loop must be provided by the user. The "on" current must be 5mA minimum and 30mA maximum. A series input resistor is provided to allow direct voltage inputs from 5 to 15 volts.

In many applications, the output loop and the input loop can be arranged to have a common return wire so that two-way communications can be achieved with 3 wires. The serial output is slaved to the parallel output and cannot be made independent. The nonisolated REQ line or the isolated SERIAL INPUT loop will activate both outputs.

The serial output can operate at two baud rates controlled by the CHARACTER BAUD RATE line (pin 32). When pin 32 is open or high, (logic "1") the rate is set at 1200 baud. Pulling pin 32 low (logic "0") changes the rate to 300 baud.

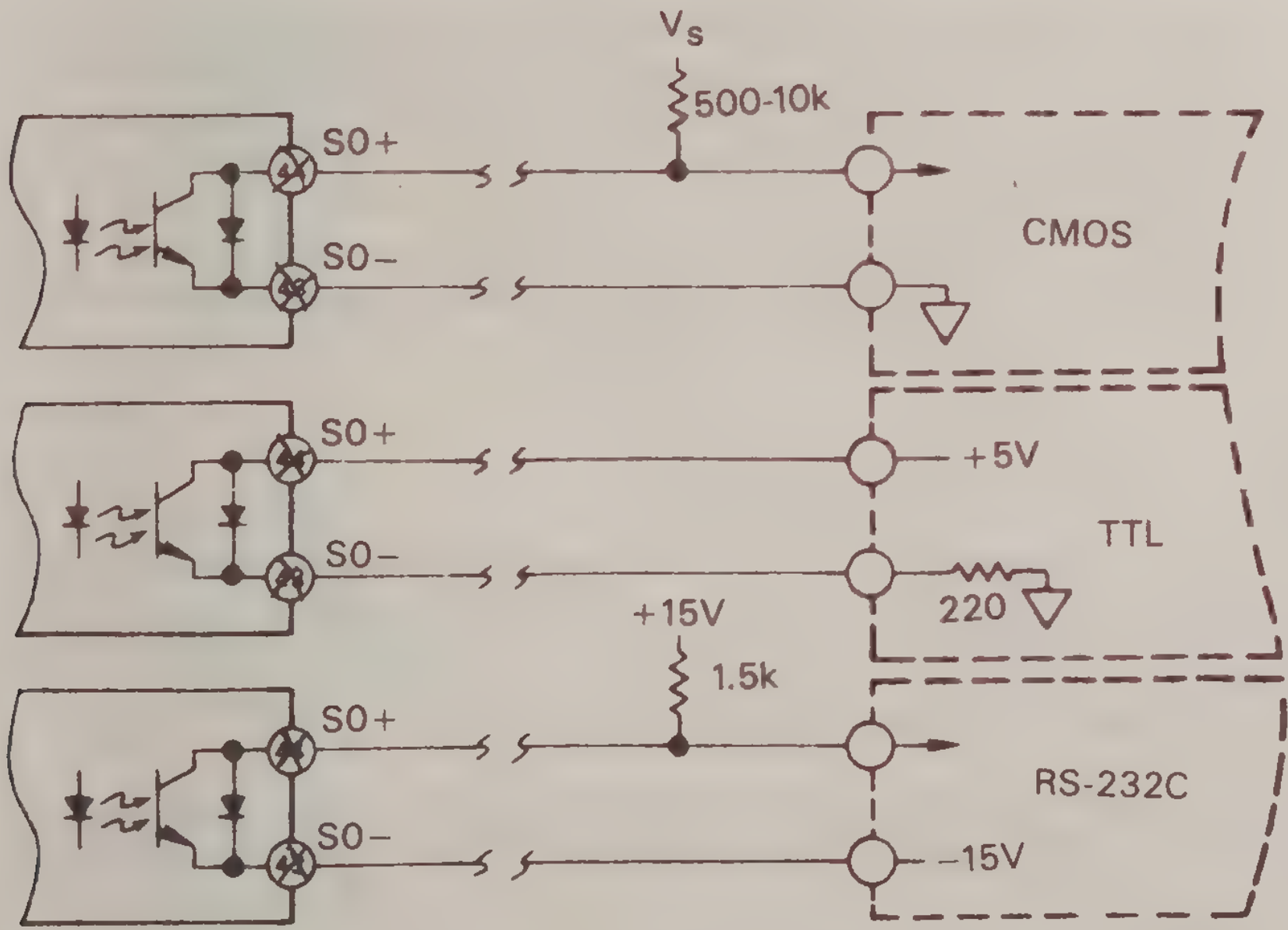


Figure 3.9 Examples of Interfacing the 650/660 Serial Output to CMOS, TTL and RS-232C Compatible Devices

When the REQ line is held low, the 650/660 will output data after every thermocouple measurement. The data will appear to come in bursts of 7 readings with a pause in between. The pause is due to the meter calibration cycle that occurs after every 7 temperature measurements. Since no new information is obtained during a calibration cycle, the digital output is inhibited.

The optional serial output also includes a complimentary strobe signal for the parallel outputs, +5V power (@ 10mA), a nonisolated TTL compatible serial output (NISO), and additional ground connections for ease of wiring.

3.3.5 ANALOG OUTPUT (Optional)

Shown in Figure 3.10 is the simplified block diagram of the optional analog output. It consists of a 12 bit digital to analog converter followed by an amplifier that provides a 1mV per degree output voltage for either the Fahrenheit or Celsuis temperature scales. This output voltage is also compensated for cold junction effects and thermocouple linearization.

There are two potentiometers provided for analog output gain and offset adjustment that are accessible under the front lens. Calibration is shown in Section 5.

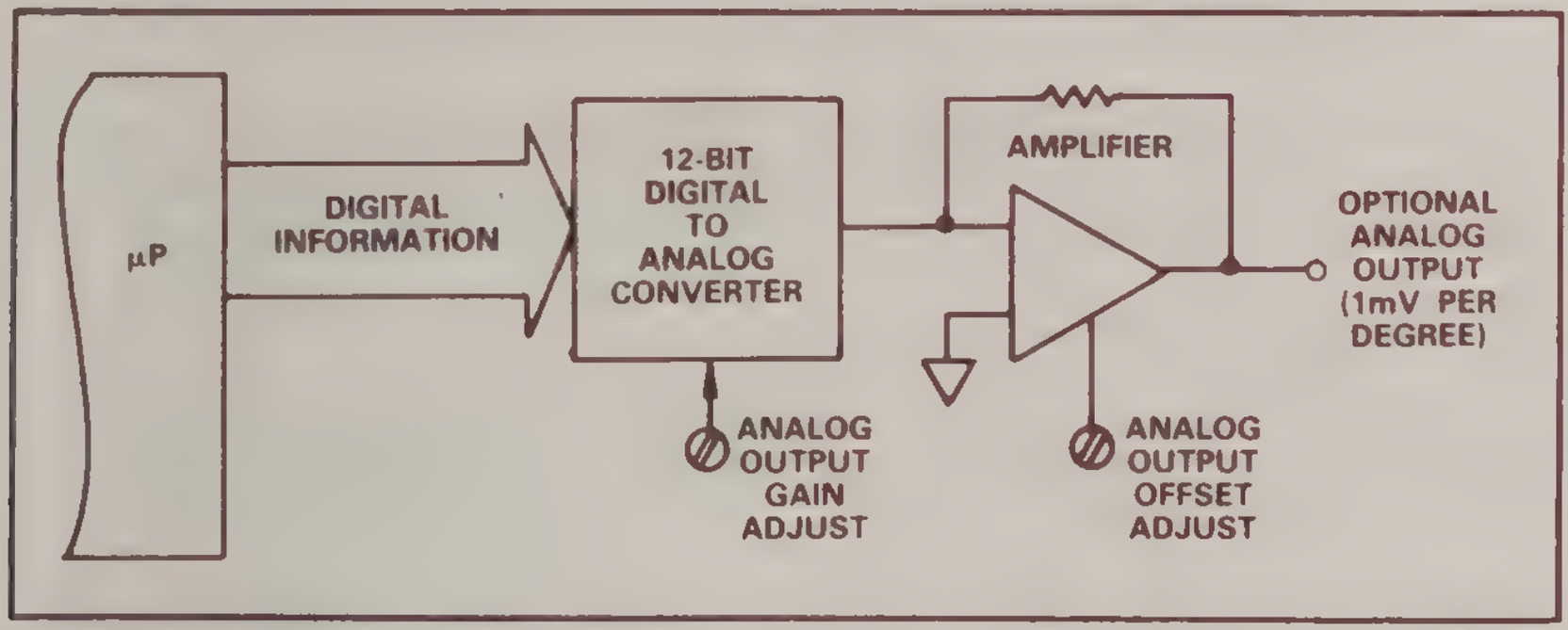


Figure 3.10 Optional Analog Output

3.3.6 POWER SUPPLY

The Model 650/660 Series is configured in three power input versions: 120Vac, 240Vac, and +7.5Vdc to + 28V dc. The AC versions are configured at the factory by programming the input transformer primary windings. The +7.5Vdc to + 28V dc versions uses the same power input terminals as the AC versions but its input goes directly to a dc regulator. The Model 650/660 Series is designed so that only one ground may be connected to the unit. If you must use a grounded thermocouple, do not use the optional analog output to drive a device whose input is grounded. Measurement errors and possible unit damage could occur if this condition is allowed to exist.

4.1 GENERAL

The contents of this section will provide the user with general information relating to the shipping configuration, proper mounting techniques, and all the connections that are necessary for proper meter operation, programming and applications.

4.2 SHIPPING CONFIGURATION

The Model 650/660 Series are shipped fully assembled including the designated options. They are completely surrounded by a shock absorbant foam and installed in their own shipping carton.

Included with the Model 650/660 Series meter are the Owner's Manual and a connector for the ASCII digital output board.

Upon receipt of the meter, inspect the container for any signs of damage in transit, and note any evidence of excessive rough handling. Report any apparent damage immediately to the shipping agent.

After examining the meter, be sure to save the shock absorbant foam and the carton should a need arise for reshipment.

4.3 MOUNTING

The Model 650/660 Series can be easily mounted in a front panel (shown in Figure 4.1) having a thickness ranging from 1/16" (1.5mm) to 3/16" (4.8mm). All terminations can be connected, from the rear, with the meter mounted or not.

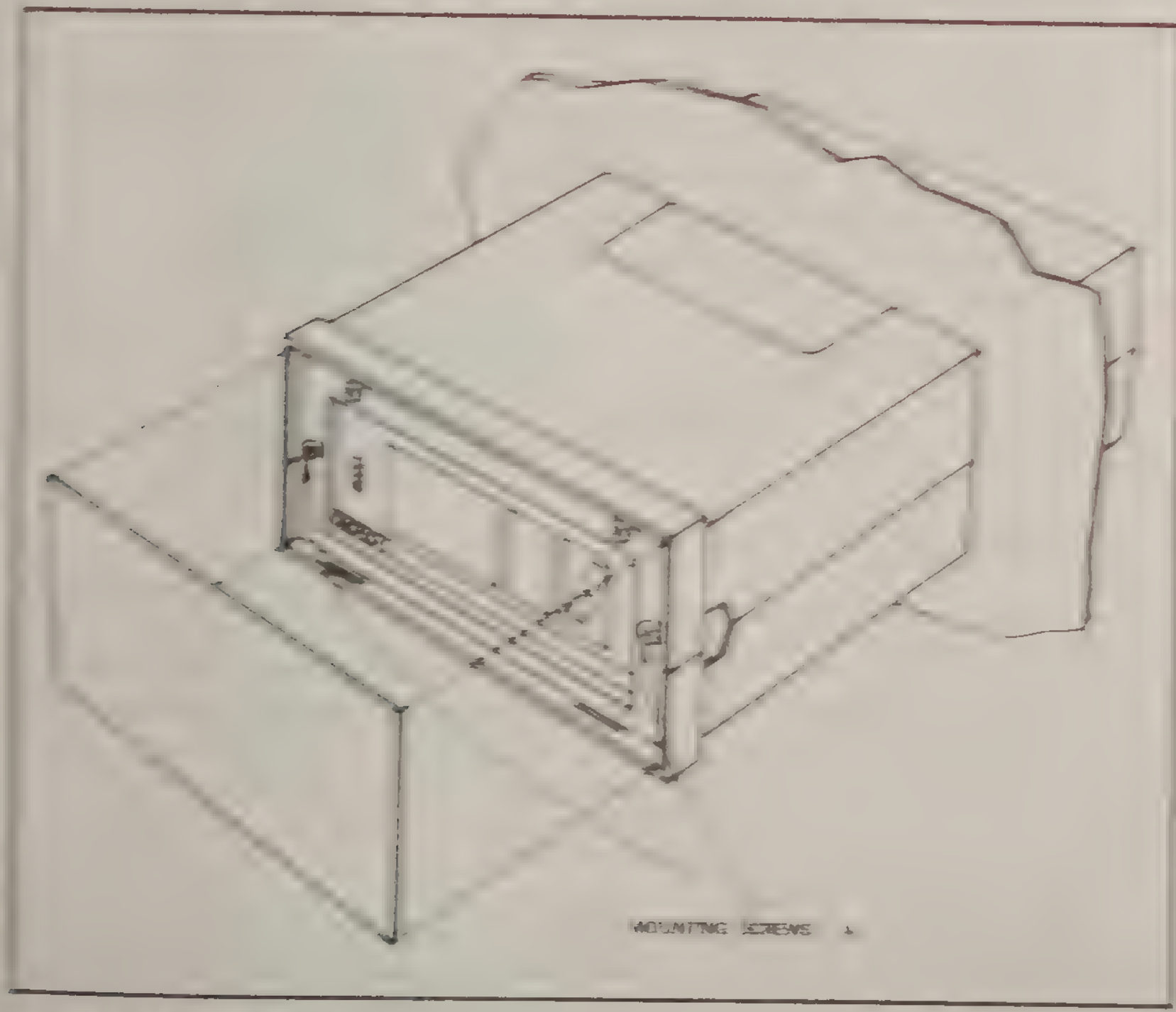


Figure 4.1 Installation

Mounting is performed by:

1. Remove the front lens by placing a small screwdriver in the notch, located on the left side of the lens, and gently pushing it to the right until the lens snaps out.

2. Pull all of the thermocouple, power input, digital output board, and (optional) analog output wires through the mounting hole and connect them to the proper terminations.

3. Place the meter into the mounting slot until it is flush with the front panel.

4. Tighten the two mounting screws (A), shown on either side of the case, until they are snug.

5. Place the lens back on the front of the meter.

> WARNING: Be sure power cord is not plugged in when attaching the line voltage wires to unit. Do not plug in until the installation is complete.

4.4 CONNECTING THERMOCOUPLES

Two solderless screw terminals are provided on the rear of the meter for thermocouple connection (shown in Figure 4.2). Connect the red lead from the thermocouple to negative terminal and the other thermocouple lead to the positive terminal.

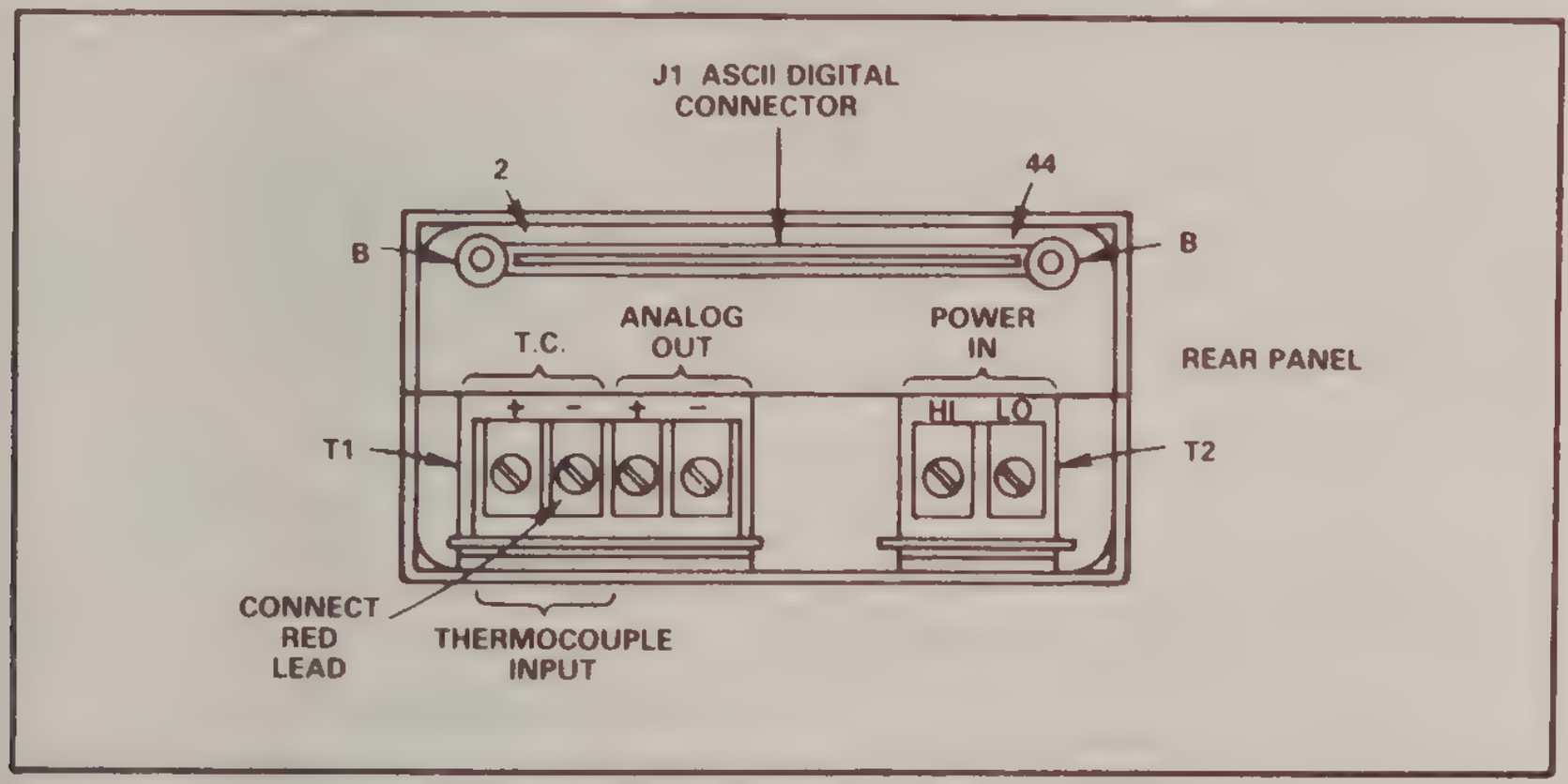


Figure 4.2 Rear Panel

NOTE: Refer to the diagrams at the rear of this manual for wiring the 650/660 with a DS, DS-01, DSS or DSS-01 option.

The Model 650/660 provides protection (AC version only) against high common mode voltages as high as 1400V peak, that may be present between the thermocouple ground and the power supply ground (shown in Figure 4.3). The Model 650/660 also has provided protection up to 300V peak across the thermocouple inputs in case one side is accidentally shorted to a 240Vac rms power line.

Care must be taken to insure that only one ground is connected to the meter. Inaccuracies in measurement and damage to the meter could otherwise result. (Refer to Section 1.2, 4.3, and 4.6.)

CAUTION: Observe Polarity: The red lead is negative "–" and is attached to the terminal labeled "–".

4.4.1 THERMOCOUPLE APPLICATIONS

Illustrated in Figure 4.4, the Model 650/660 is used to measure temperature that is physically a long distance from the temperature meter. Here an external ICE POINT reference is used as the reference "COLD" junction. Now, standard copper wire can connect the external ICE POINT reference to the Model 650/660. Cold junction compensation, in the meter, is provided by the ICE POINT reference and must be disabled at J1 as shown.

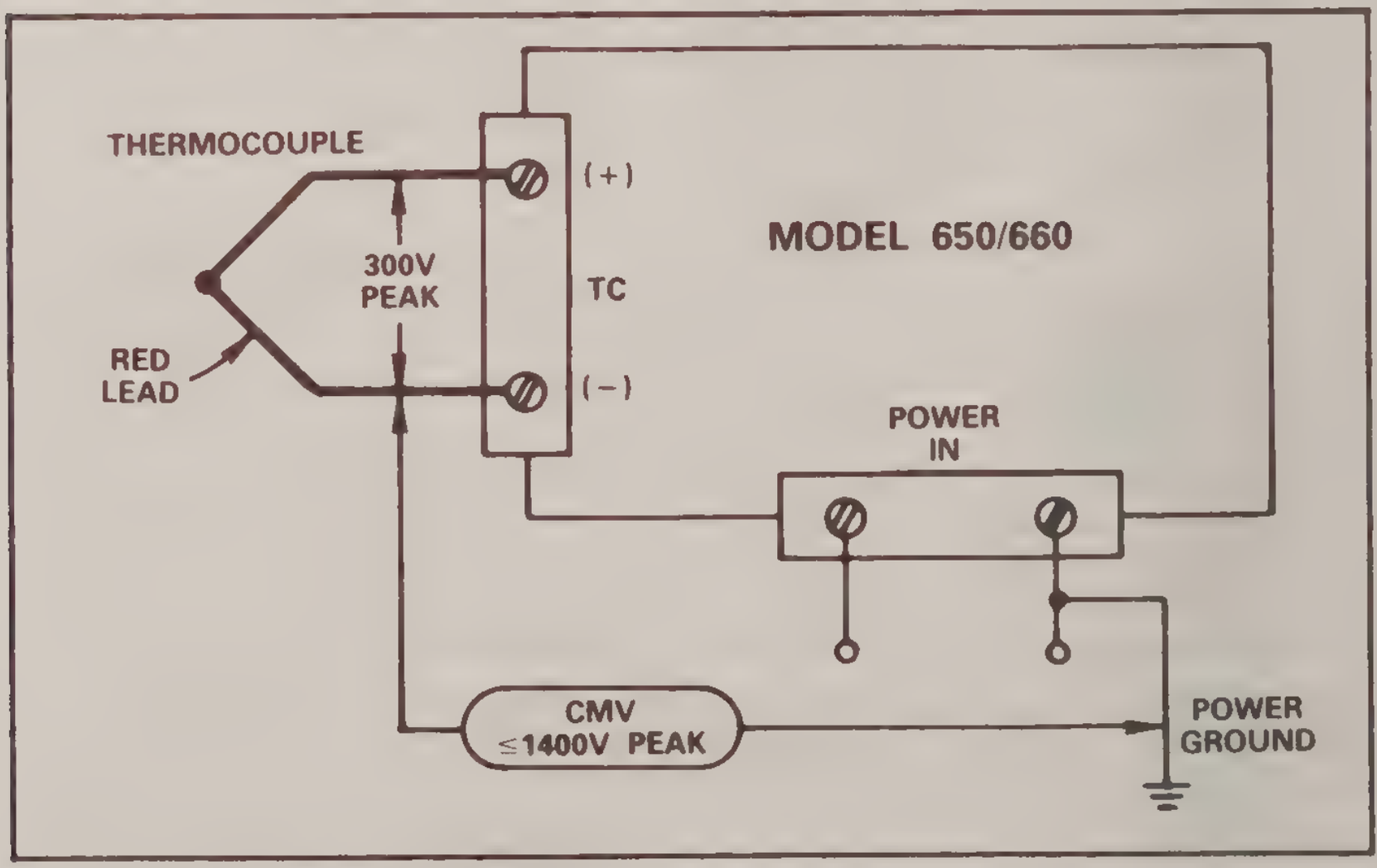


Figure 4.3 Rated CMV Specification

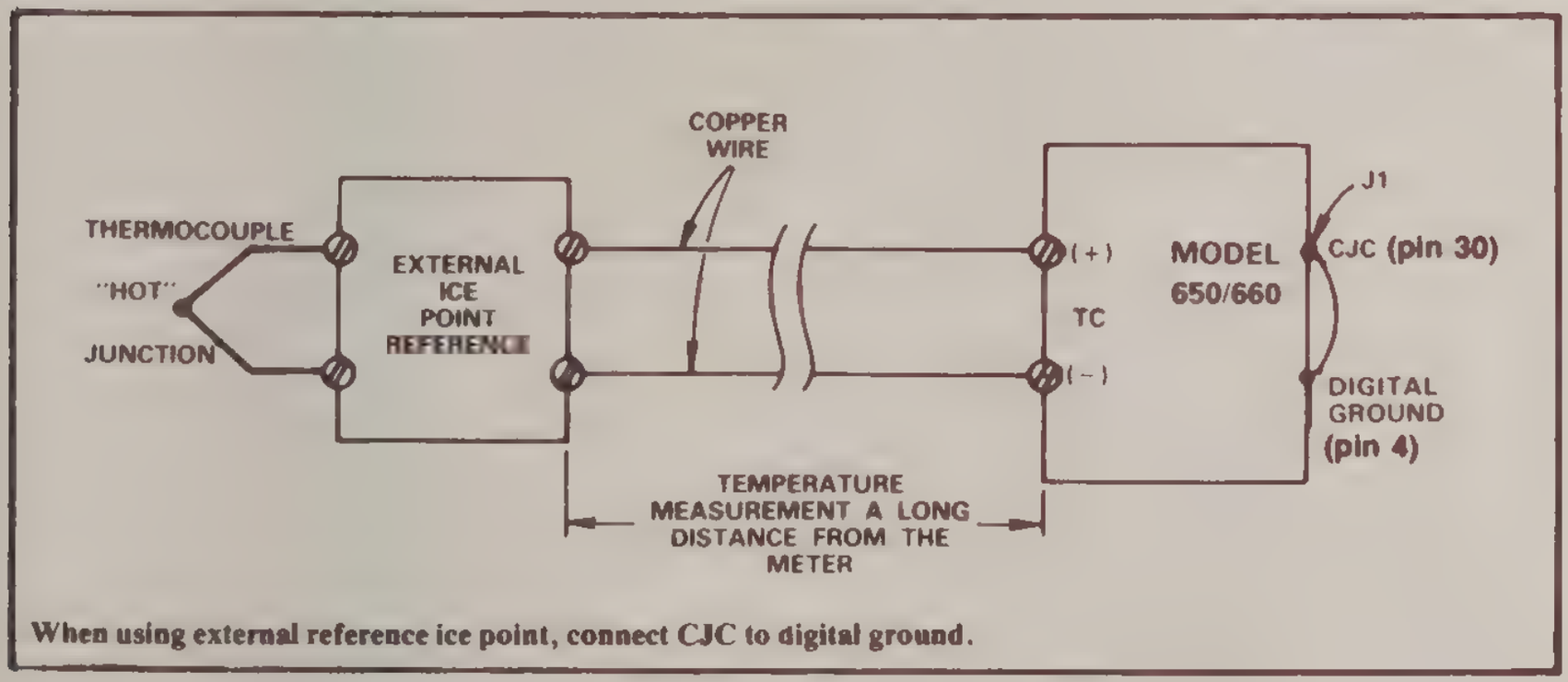


Figure 4.4 External ICE POINT Reference

A multi-channel thermocouple application is illustrated in Figure 4.5. Here the Model 650/660 and the channel scanner are sequenced by the controller to monitor a number of temperature measurement points. The controller selects the channel and requests the Model 650/660 for the digital temperature information. The same thermocouple wire must be used, between the channel scanner and Model 650/660, to provide accurate measurements.

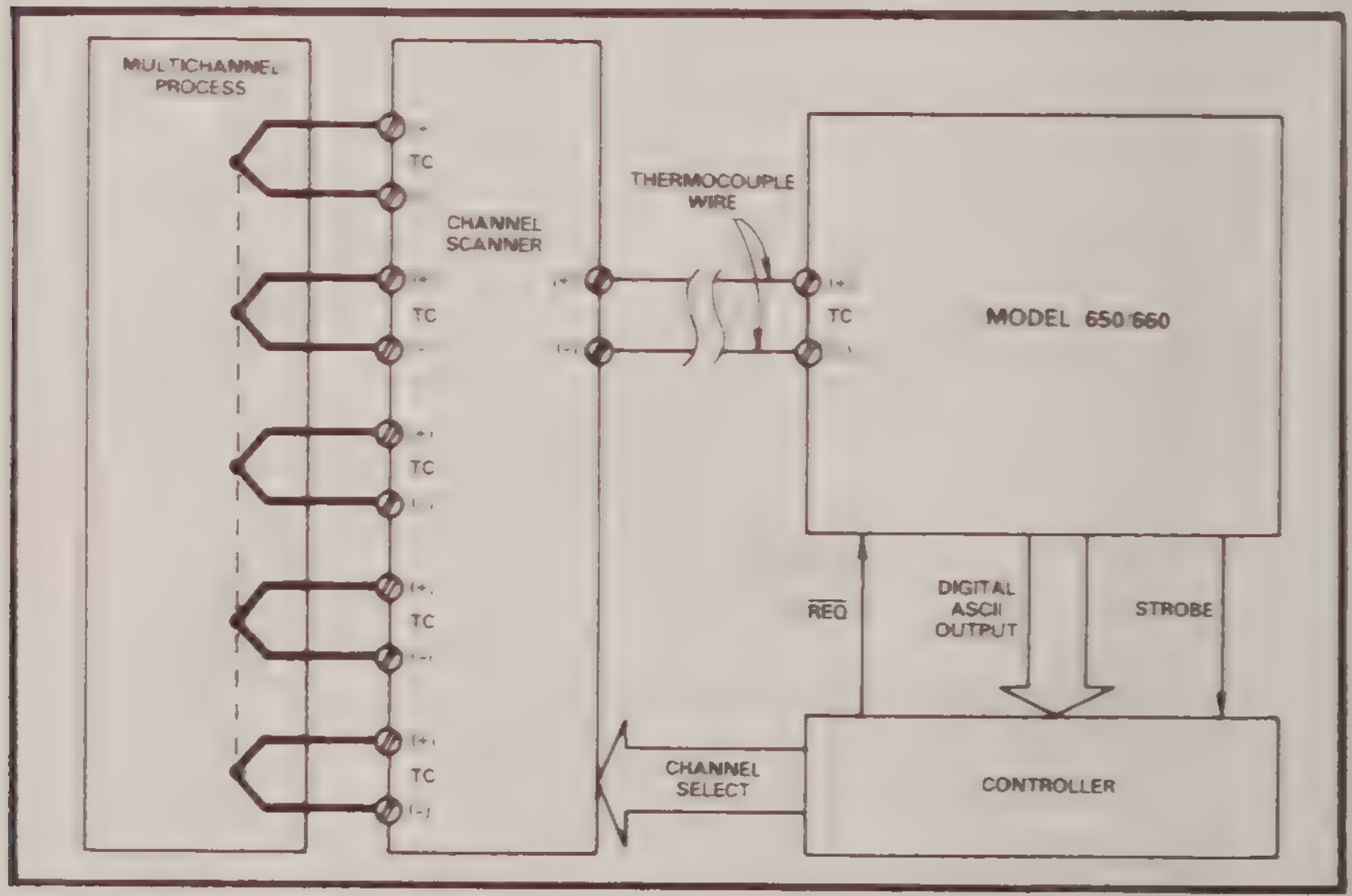


Figure 4.5 Multi-Channel T.C. Applications

4.5 CONNECTING THE ASCII DIGITAL OUTPUT BOARD

In connecting the digital outputs, output lines are provided at the rear of the meter on the PC board edge P1 (See Figure 4.2). Two screw terminals (B) are provided, on the rear of the case, so an optional connector J1 can be fastened directly to the case. Shown in Figure 4.6 are the digital output pin designations for P1.

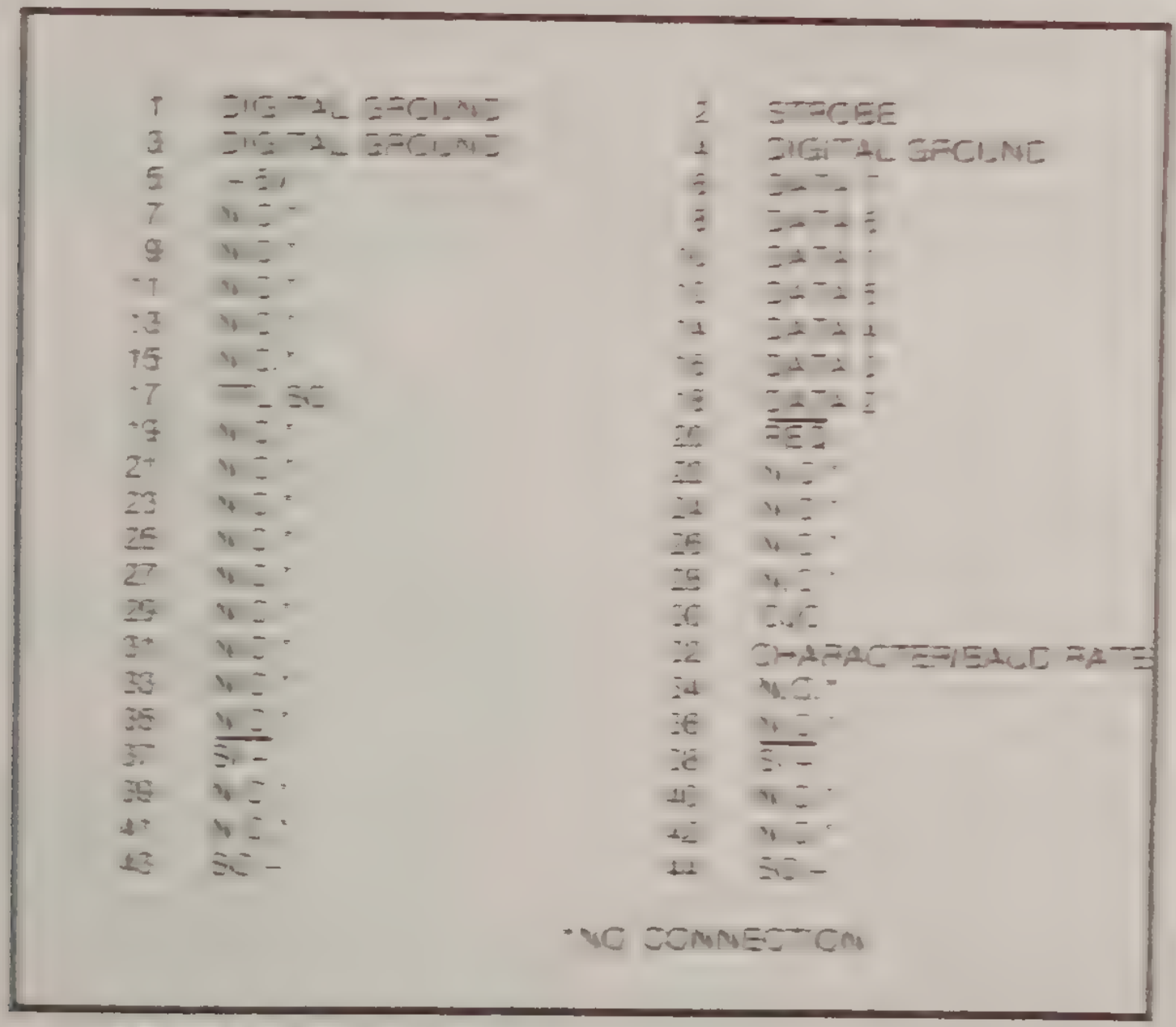


Figure 4.6. P1 Pin Designations

NOTE: Even number pins are on one side of the PC board, odd number pins if present are on bottom. Odd number pins are only supplied with option S2. All pin and Number designations on optional edge connector may not match and should be disregarded.

4.5.1 ASCII CHARACTER-SERIAL APPLICATION

Figure 4.7 shows the Model 650/660 connected to a low-cost printer that accepts the standard ASCII input format. Enabling the REQ line (logic "0") initiates a digital output sequence following the last meter conversion cycle. The 9 ASCII characters are transmitted to the printer in bit-parallel, character-serial format, in the following sequence:

Character	1	2	3	4	5	6	7	8	9
Data:	+	1	9	9	9	(SP)	F	(CR)	(LF)

Each character is loaded into the printer on the falling edge of each STROBE pulse. The Carriage Return (CR) and Line Feed (LF) characters signal the end of data transmission, whereby the printer initiates a print cycle.

Data transmission rate is selected by the CHARACTER/BAUD RATE line (pin 32, J1). Grounding pin 32 sets the data rate at 25 characters/sec; leaving pin 32 open sets the data rate at 100 characters/sec. The CHARACTER/BAUD RATE should be selected to comply with the particular printer's data rate equipment.

Since most printers can accept data rates faster than supplied by the Model 650/660, the use of the printer BUSY signal to indicate a print cycle is optional to the user.

Some printers may require a positive-going STROBE signal to load data in the printer's input register. If such is the case, two solutions are available: (1) a complimentary STROBE signal is available on 650/660 models equipped with the SERIAL OUTPUT option (Option S2). If the meter is not equipped with the SERIAL OUTPUT option, an inexpensive inverter circuit, such as the one shown in Figure 4.8 may be used.

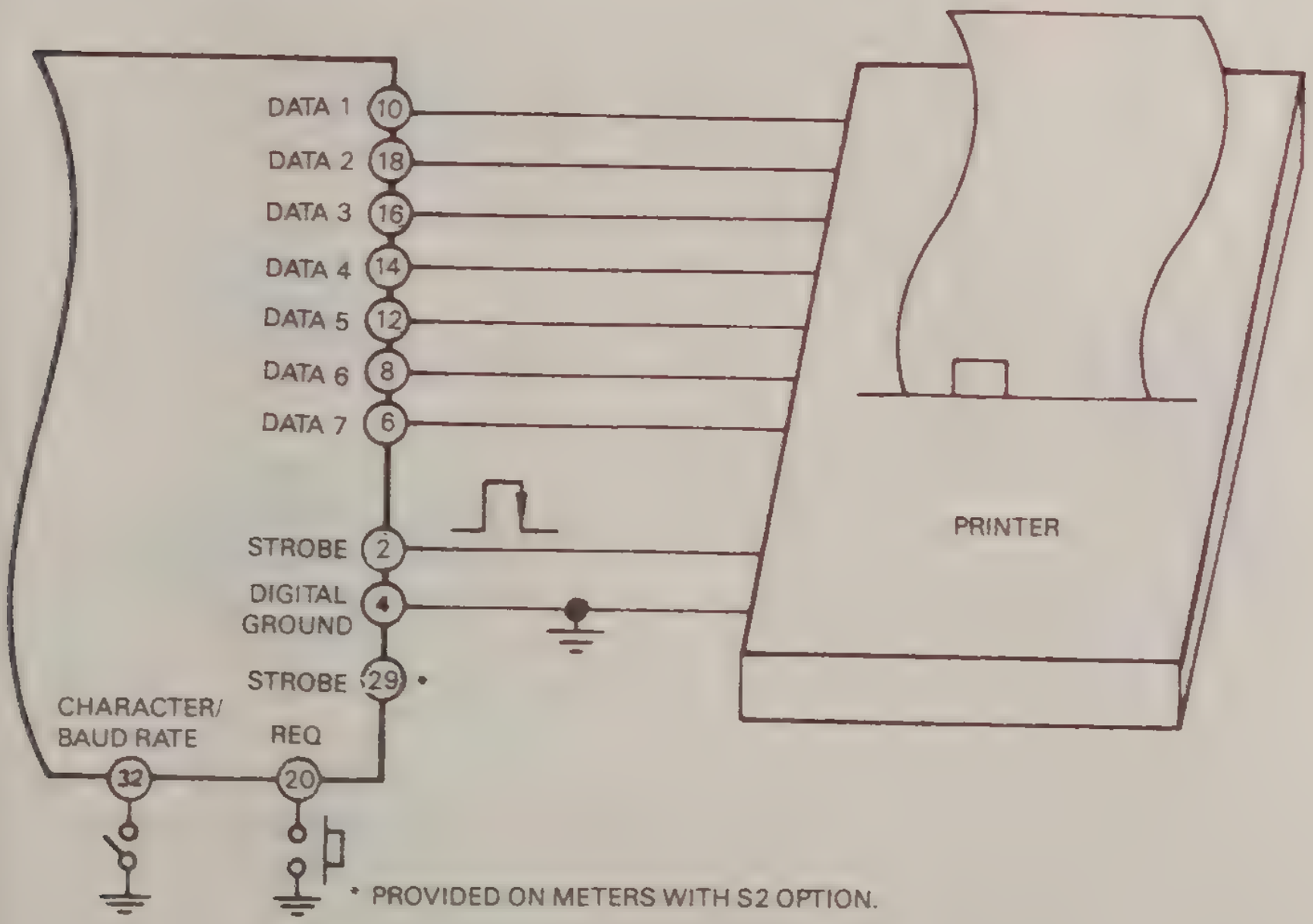


Figure 4.7 650/660 Printer Interface

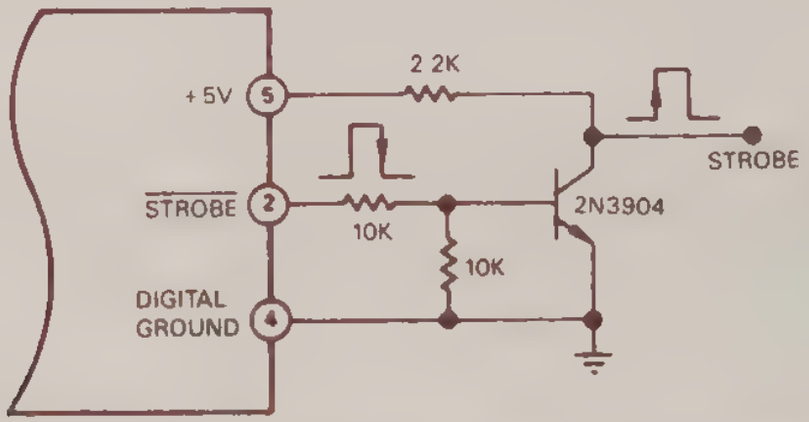


Figure 4.8 Circuit to Generate Complimentary STROBE Pulse

4.5.2 SERIAL OUTPUT APPLICATIONS

In Figure 4.9, several 650/660's are used to monitor and selectively transmit temperature data from several remote locations to a central control station several miles away. A request for the meter to transmit its temperature data is initiated by a transition from current "on" to current "off" at the isolated SERIAL INPUT. The "on" current should be 5mA minimum and 30mA maximum; an internal resistor at the SERIAL INPUT port allows the use of a voltage level from +5V to +15V. A request for data will not be recognized during data transmission.

The temperature data is transmitted via the isolated SERIAL OUTPUT to the local 2-way telecommunications interface. The SERIAL OUTPUT can be configured to interface to TTL, CMOS or RS-232C compatible input devices as previously illustrated in Figure 3.9.

The CHARACTER/BAUD RATE is selected by tying pin 32 on J1 either low (ground) for a baud rate of 300, or high (open) for a baud rate of 1200.

The 20mA serial loop will operate effectively up to 10,000 feet (3,000m) at a baud rate of 300, and up to 4,000 feet (1,200m) at a baud rate of 1200.

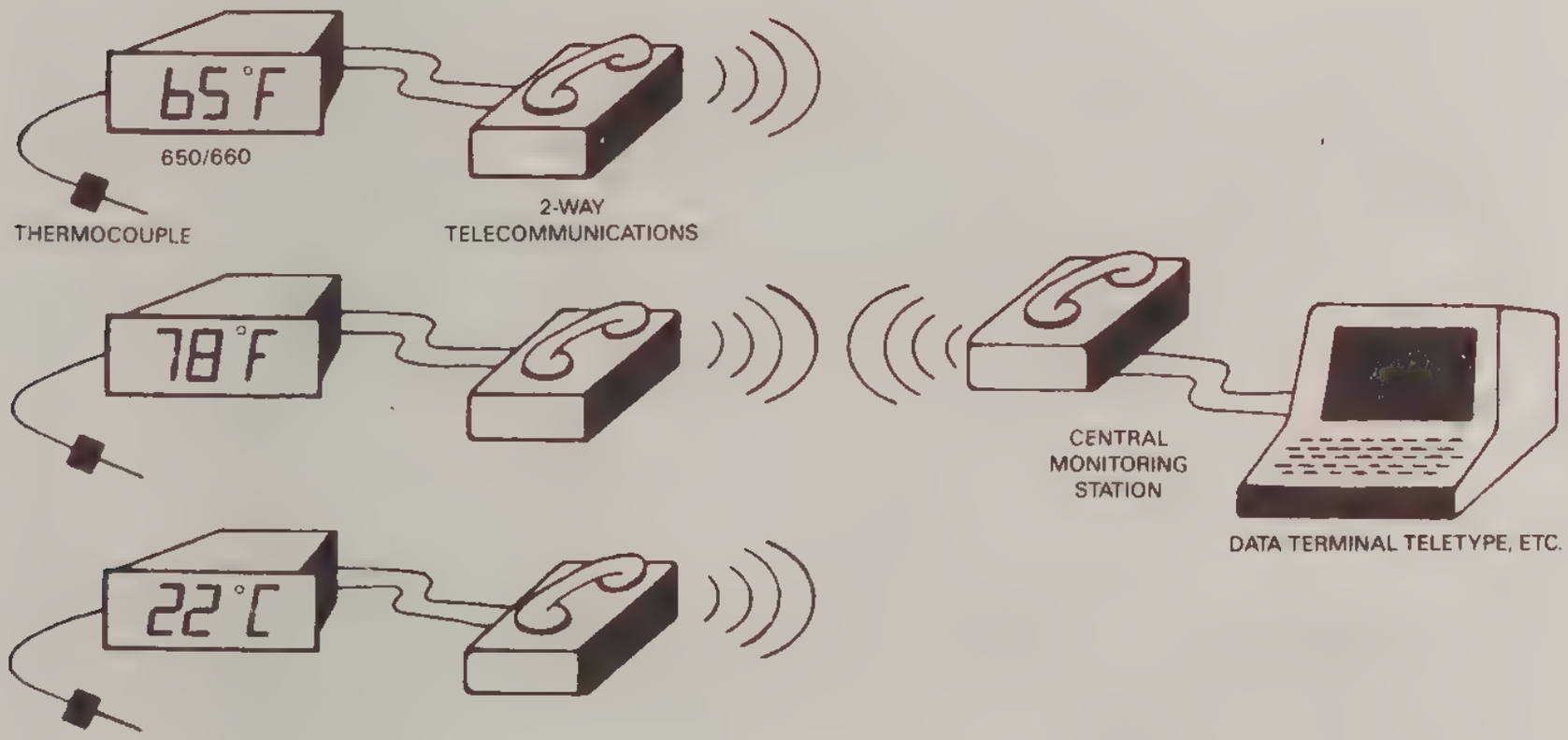


Figure 4.9 Multiple 650/660 Models Used in a Remote Temperature Monitoring Application (See Figure 4.10)

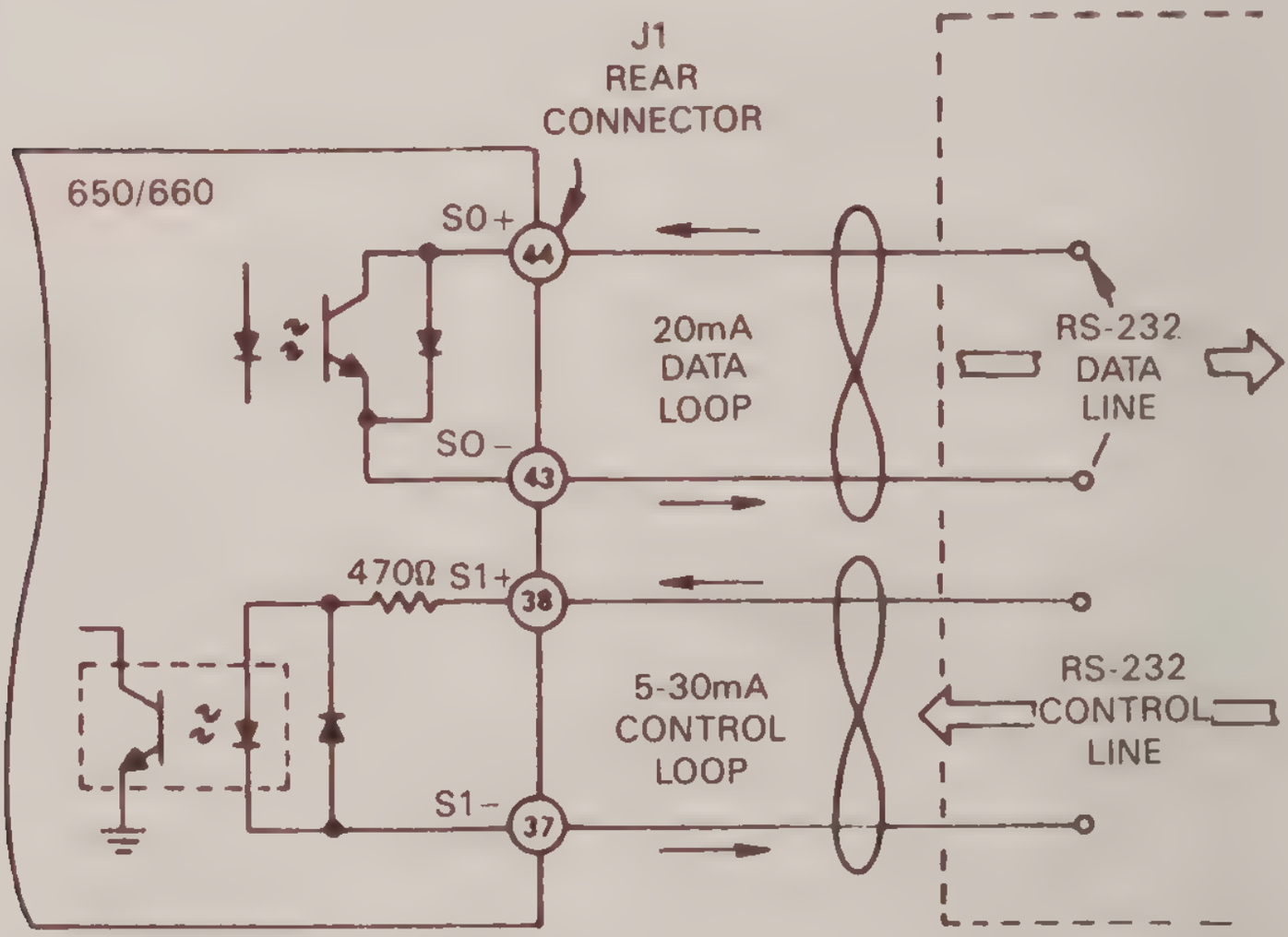


Figure 4.10 Detail of the 650/660 to Telecommunications Interface Device Shown in Figure 4.9.

4.6 CONNECTING POWER

Power is simply connected to the meter via two solderless screw terminals provided on the rear of the unit (See Figure 4.2). Before connecting the power, insure that you have the proper power option ordered shown on the meter identification label: 120VAC, 240VAC, or +7.5Vdc to + 28V dc. Because the DIN case is made of a high impact resistant plastic case grounding is not required. Since the AC power versions are transformer coupled, concern for polarity is not necessary. The DC power versions must have the supply ground connected to the "LO" Power In Terminal.

> WARNING: Be sure power cord is not plugged in when attaching the line voltage wires to unit. Do not plug in until the installation is complete.

4.7 CONNECTING ANALOG OUTPUT (OPTIONAL)

Two solderless screw terminals are provided, on the rear of the meter, for connecting the 1mV/degree linearized analog output to plotters or recording instruments. Care must be taken to observe the grounding requirements so that inaccuracies or possible unit damage is avoided.

GROUNDING NOTE:

The Model 650/660 Series is designed so that only one ground may be connected to the unit. If you must use a grounded thermocouple, do not use the optional analog output to drive a device whose input is grounded. Measurement errors and possible unit damage could occur if this condition is allowed to exist.

4.7.1 ANALOG OUTPUT APPLICATIONS

Illustrated in Figure 4.11 the 1mV/degree analog output of the Model 650/660 is used to drive a strip chart recorder for long term temperature monitoring.

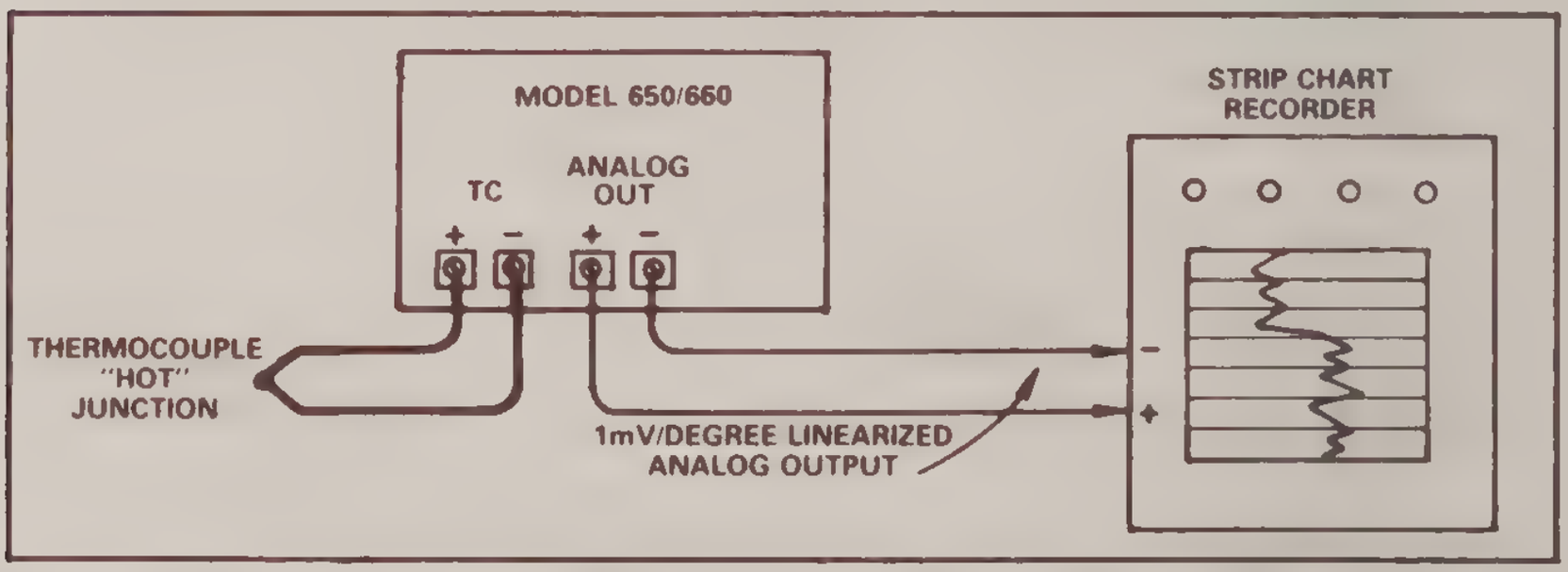


Figure 4.11 Interfacing the Model 650/660 Analog Output to a Strip Chart Recorder

Figure 4.12 illustrates the analog output of the Model 650/660 driving a remote set point alarm. Here, high and low temperature points can be set to address critical temperature applications.

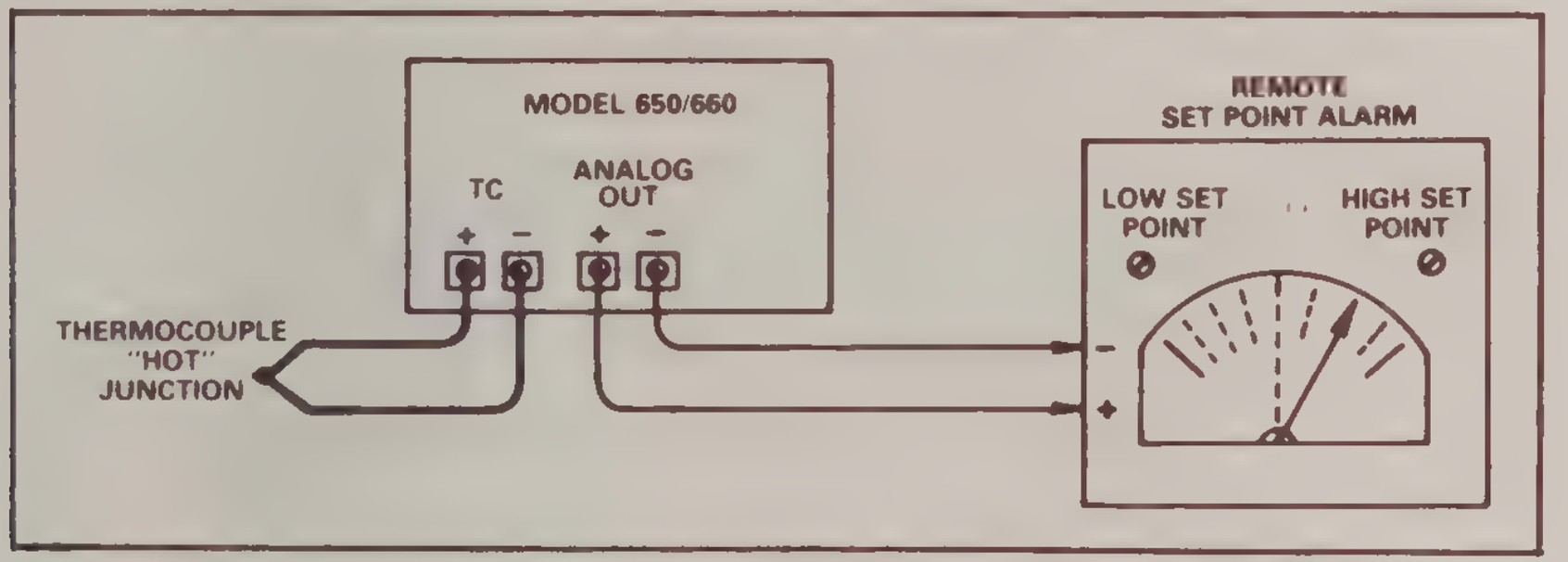


Figure 4.12 Interfacing the Model 650/660 to a Digital or Analog Remote Set Point Alarm

Figure 4.13 illustrates the analog output of the Model 650/660 to interface to a 4 to 20 mA current loop. The signal conditioner is used to amplify the analog output level while the V to I converter interfaces to the loop.

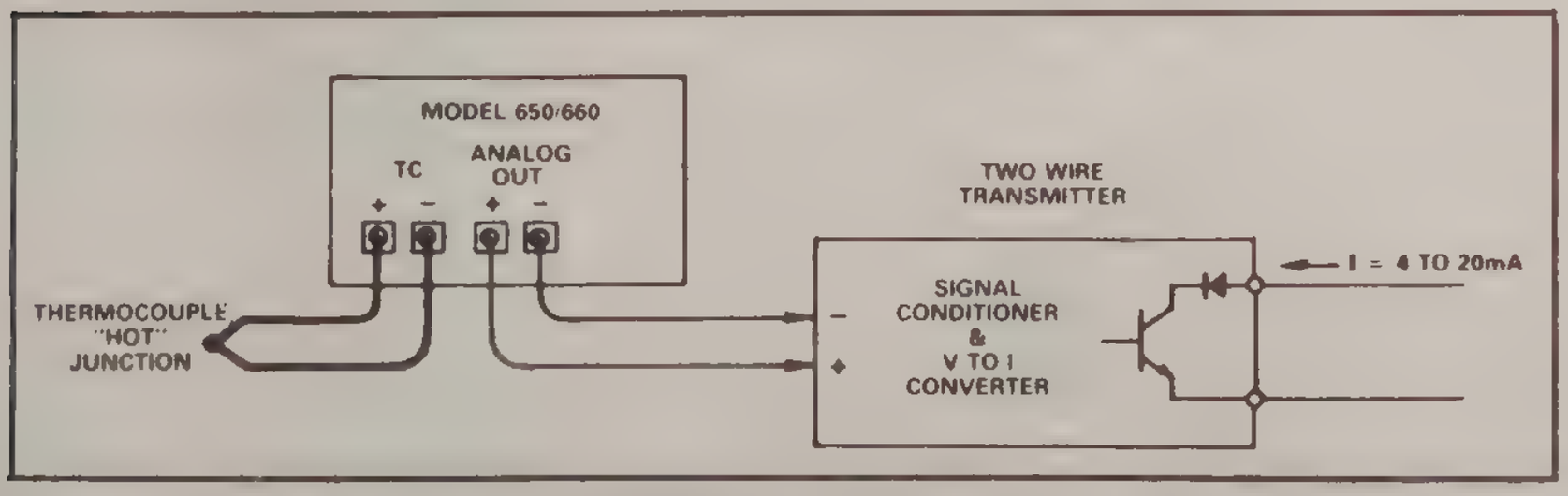
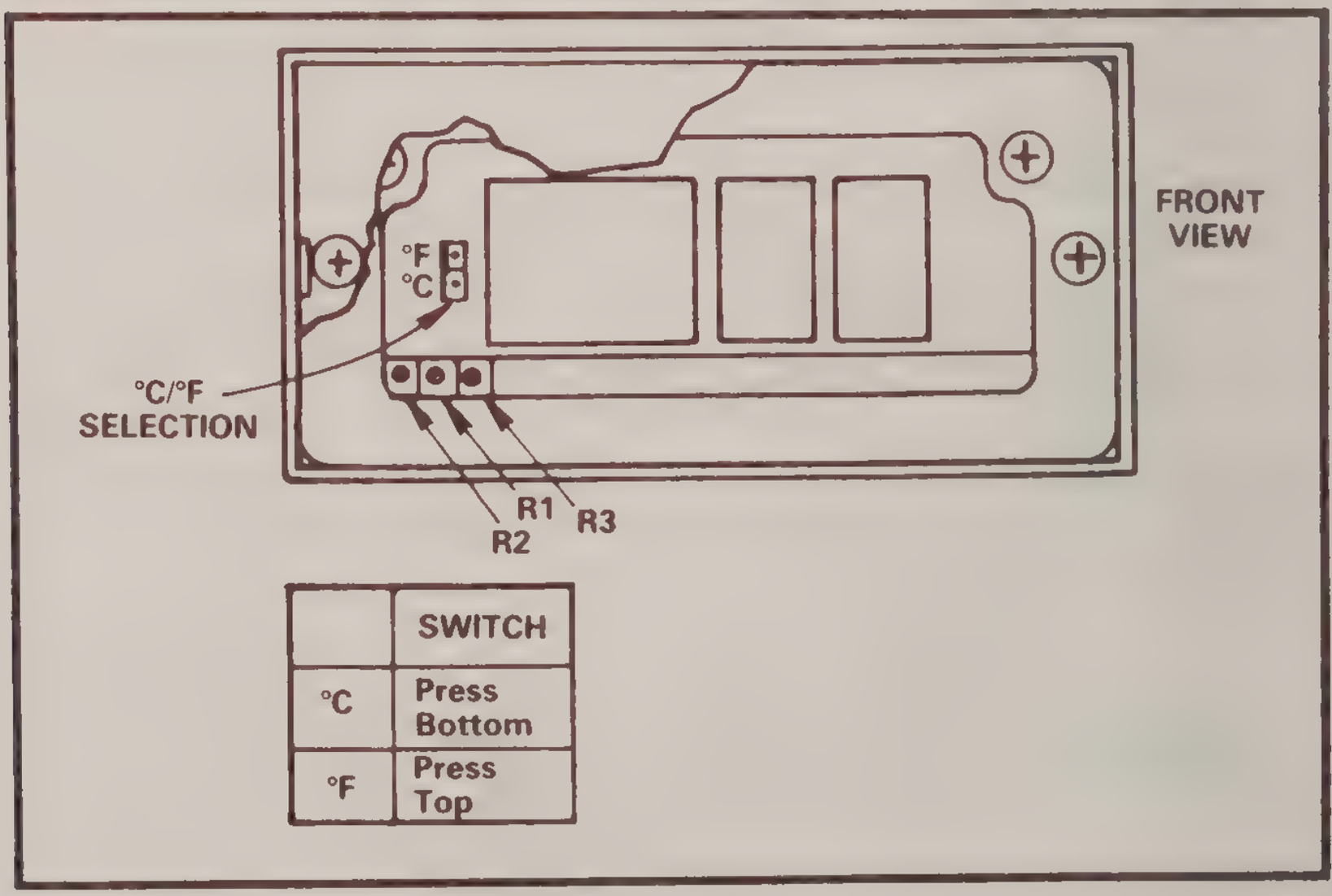


Figure 4.13 Interfacing the Model 650/660 to a 4-20 mA Current Loop

4.8 °C/°F SECTION

°C/°F section is performed by either single-pole switches or by a jumper wire connection of two sockets located behind the front lens on the left side of the display board (shown in Figure 4.14). By pressing the bottom part of the switch or leaving these sockets open, temperature will be scaled in degrees Celsius. Pressing the top part of the switch or connecting the sockets together with a jumper wire will yield degrees Fahrenheit scaling.



	SWITCH
°C	Press Bottom
°F	Press Top

Figure 4.14 °C/°F Selection

4.9 MODEL 660 THERMOCOUPLE PROGRAMMING

This option is provided only with the Model 660 units. Thermocouple programming is provided by selecting the appropriate (S1) DIP switch position as shown in Table 4.1 below. S1 is located on the ASCII digital output board, shown in Figure 4.15. Access to S1 requires removal of only the display board from the case.

THERMOCOUPLE TYPE	TC1	TC2	TC3
J	O	O	O
K	C	O	O
T	O	C	O
E	C	C	O
S	O	O	C
R	C	O	C

O = Open
C = Close

Table 4.1. Model 660 Dip Switch Programming

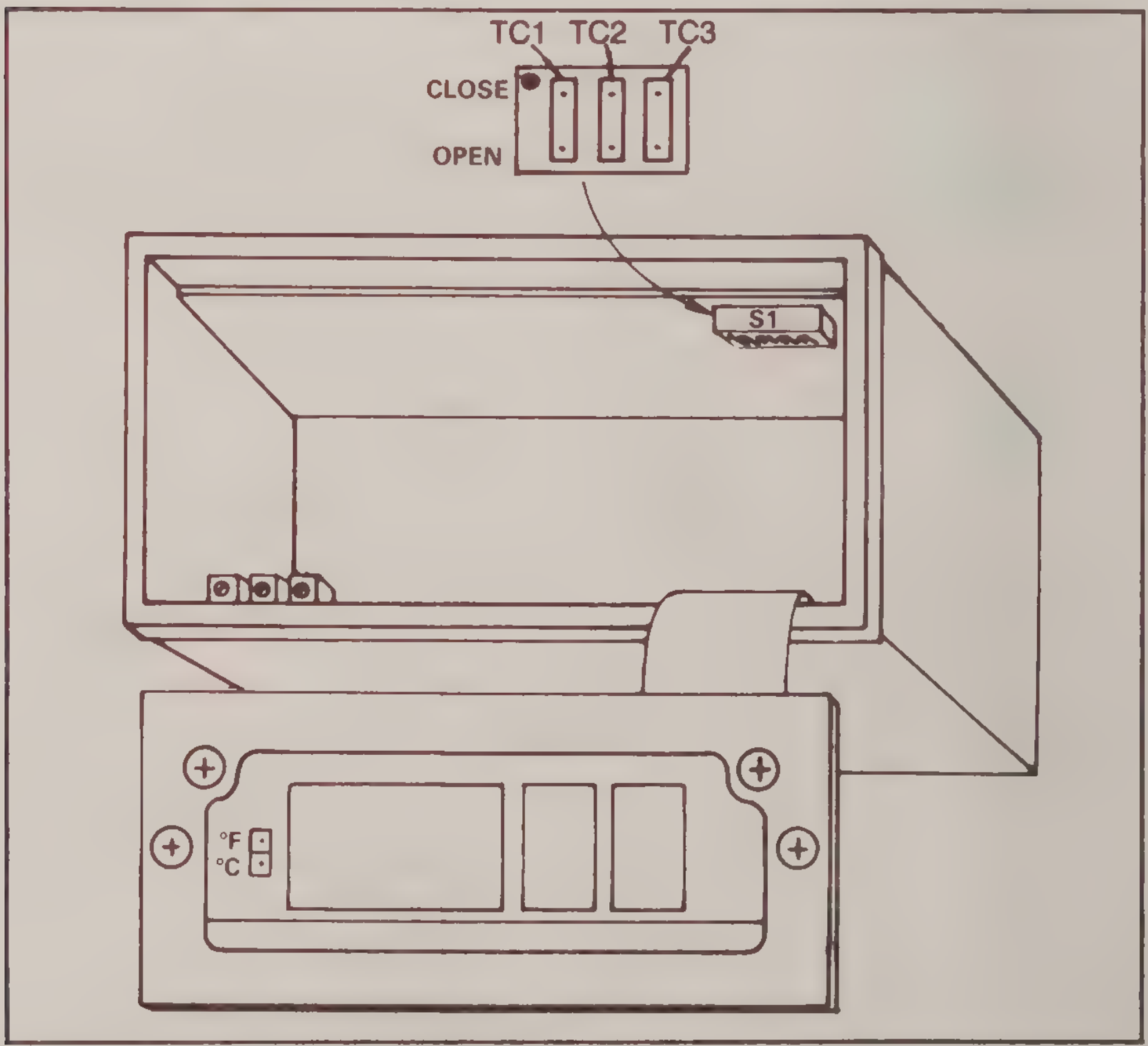


Figure 4.15 Model 660 Thermocouple Programming

5.1 GENERAL

This section describes the proper calibration procedures. Each Model 650/660 is factory calibrated to provide optimum performance for the designated thermocouple type. Although these meters are microprocessor based, a simple reference calibration must be performed periodically to insure accuracy is maintained. For models containing the analog output option, gain and offset calibration must also be made.

The self-calibration techniques used are implemented in two modes: 1) at power turn-on, and 2) during normal meter operation. At power turn-on, self-calibration is performed at a rapid rate for approximately three seconds. During this time, several measurements of each calibration parameter are made which rapidly updates their stored factors. For normal operation, the calibration factors are updated periodically with some firmware filtering included to eliminate any noise and transient related inaccuracies. Because firmware filtering is used, any attempts to adjust the meters gain potentiometer will seem to have no immediate affect. By removing power momentarily and reapplying it after each gain adjustment, this will place the meter in the power turn-on mode and thus significantly reducing the calibration time.

5.2 CALIBRATION SET UP

1. Turn power off. For convenience, insert an on-off switch in the power line connection of the meter (shown in Figure 5.1).
2. Disable the cold junction compensation circuitry by connecting the CJC (pin 30) to digital ground (pin 4) on the digital output board connector J1.
3. Connect an accurate (0.01%) millivolt source to the thermocouple input terminals.

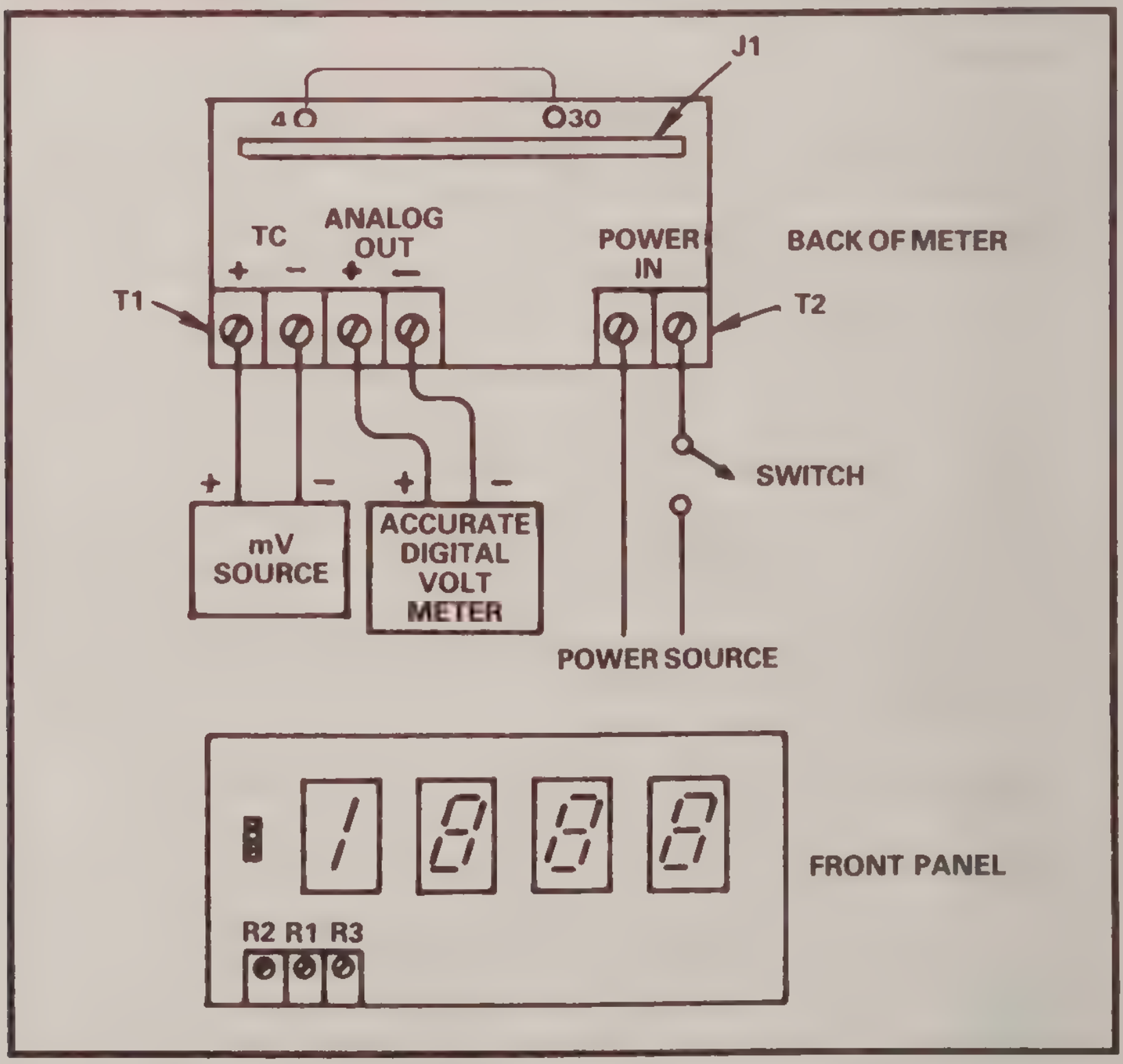


Figure 5.1. Calibration Set Up

4. For analog output versions, connect an accurate digital volt meter to the analog output terminals. Be sure to observe that grounding requirements are maintained.
5. Remove the front lens from the meter and locate the proper adjustment potentiometers.

5.3 CALIBRATION PROCEDURE

METER GAIN CALIBRATION

1. Refer to Table 5.1 for the proper thermocouple and output calibration settings.
2. Set the input millivolt source to the proper value for the selected thermocouple meter as shown.
3. Turn the power on.
4. The meter goes through a self-calibration sequence for three seconds placing the proper offset, gain and CJC constants in memory. During this self-calibration mode, the display reads + 1888.
5. After the 3 second self-calibration sequence, the meter will produce a reading proportional to the input millivolt source. Compare the display reading to the corresponding value indicated in Table 5.1.
6. If the display reading is greater than the required value, compensate by turning the potentiometer R1 counterclockwise.

   NOTE: Adjusting R1 will have little or no effect initially on the display reading. Momentarily remove power from the meter and apply it again. This will cause the meter to perform a fast self-calibration and will indicate a new display reading.

   If the display reading is less than that required, compensate by turning potentiometer R1 clockwise.
7. Repeat step 6 until the display reading corresponds to the reading shown in Table 5.1.
8. Disconnecting pins 4 and 30 completes the meter calibration.

THERMOCOUPLE TYPE	MILLIVOLT SOURCE VOLTAGE (mV)	DISPLAY READING °C	°F
J	39.754	710	1310
K	43.585	1060	1940
T	18.420	360	680
E	61.806	810	1490
S	17.942	1700	—
R	20.215	1700	—

Table 5.1. Meter Gain Calibration

ANALOG OUTPUT CALIBRATION

1. Meter gain calibration should be performed prior to this procedure to insure accuracy is attained.
2. Refer to Tables 5.2 and 5.3 for the proper thermocouple vs. analog output calibration settings.
3. Determine if °C or °F scaling is selected. °F is recommended for calibration purposes due to its wider range for the J, T, and E type thermocouples.
4. Disable the CJC by connecting pins 4 and 30 together on J1.

OFFSET

1. Set the millivolt source to the value corresponding to the thermocouple type used and the °C/°F scaling shown in Table 5.2. The display will read the corresponding value.
2. Measure the analog output voltage. If its value is other than that shown, adjust R_3 until these values match.

GAIN

1. Set the millivolt source to the value corresponding to the thermocouple type used shown in Table 5.3. The display will read the value shown in °C or °F.
2. Measure the analog output voltage. If its value is other than shown, adjust R_2 until these values match.
3. Remove jumper from Pins 4 and 30 on J1 to complete calibration.

Thermocouple Type	Millivolt Source Voltage (mV)		Display Reading	R_3 Adjustment Analog Output Voltage
	°C	°F		
J	0.000	−0.885	+ 000	0.000V
K	0.000	−0.692	+ 000	0.000V
T	0.000	−0.692	+ 000	0.000V
E	0.000	−1.026	+ 000	0.000V
S (10°C)	0.055	—	+10	10mV
(50°F)	—	0.055	+ 50	50mV
R (10°C)	0.054	—	+10	10mV
(50°F)	—	0.054	+50	50mV

Table 5.2. Analog Output Offset Calibration

Thermocouple Type	Millivolt Source Voltage (mV)	Display Reading		R_2 Adjustment Analog Output Voltage	
		°C	°F	°C	°F
J	39.754	+ 710	1310	710mV	1310mV
K	43.585	+1060	1940	1060mV	1940mV
T	18.420	+ 360	680	360mV	680mV
E	61.806	+ 810	1490	810mV	1490mV
S (°C/°F)	17.942/10.544	+1700	1980	1700mV	1980mV
R (°C/°F)	20.215/11.605	+1700	1980	1700mV	1980mV

Table 5.3. Analog Output Gain Calibration

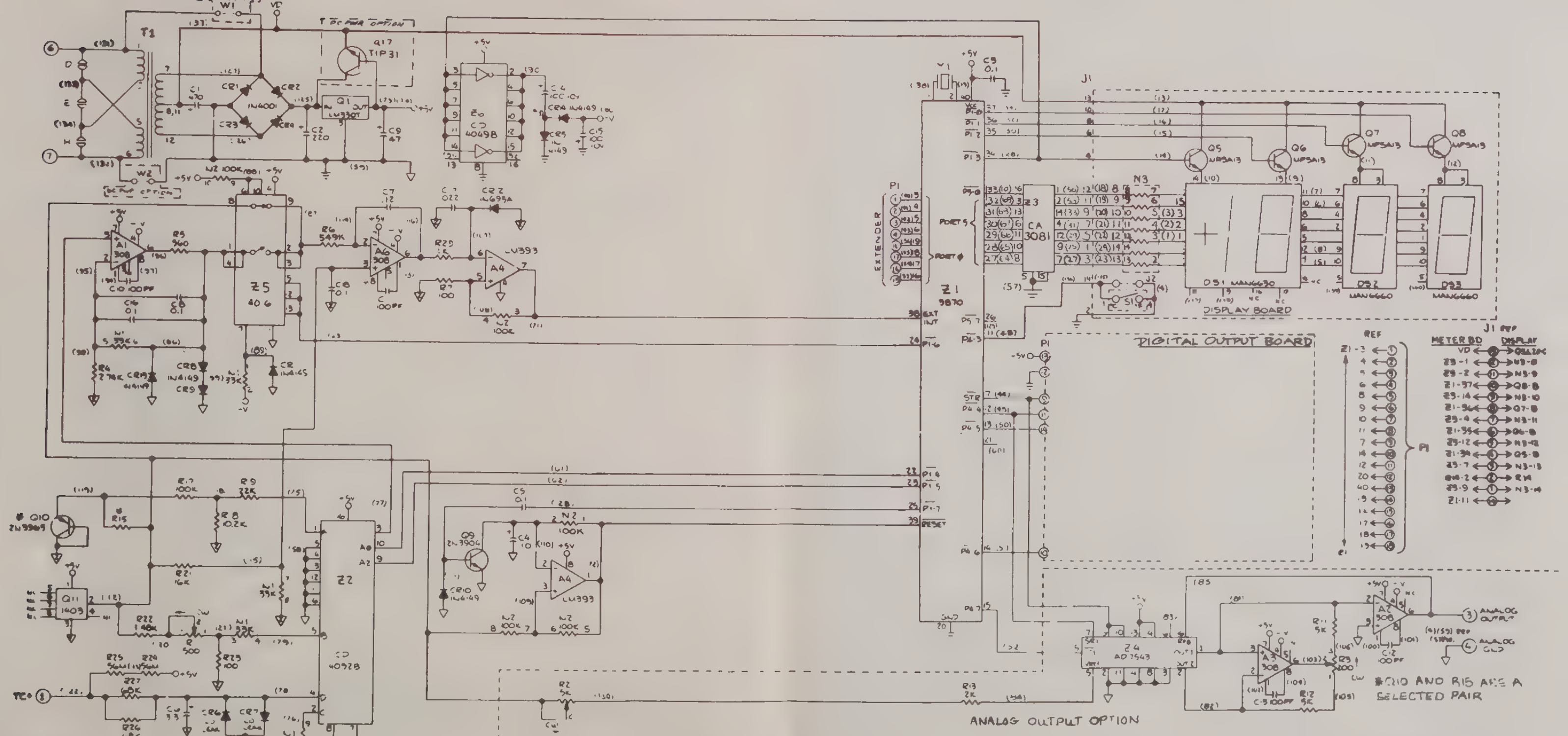
6
SERVICE INFORMATION

6. Service Information

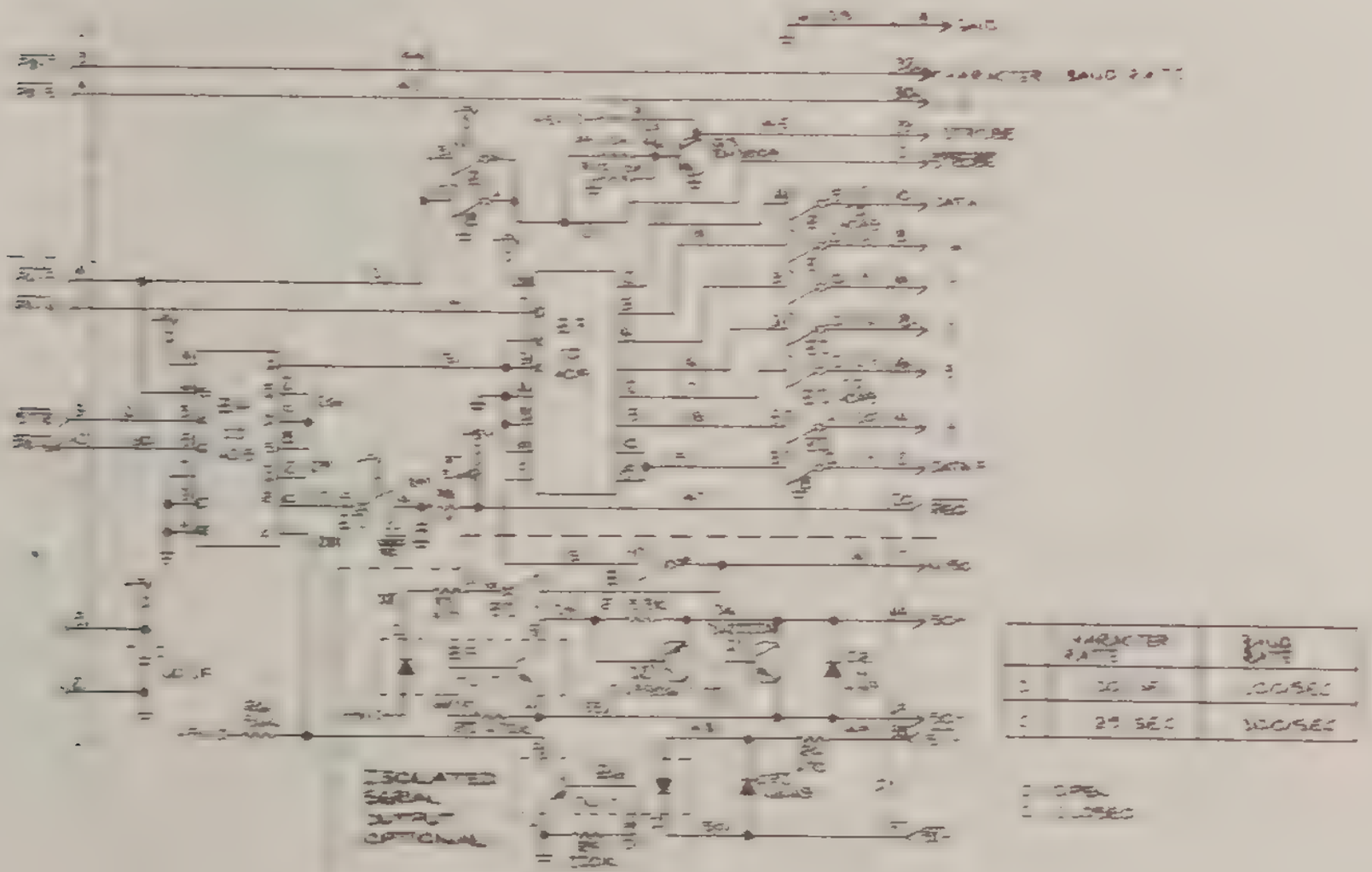
Each Model 650/660 Series is covered by a 13-month warranty described on the inside of the front cover.

DURING THE WARRANTY PERIOD THIS WARRANTY WILL BE VOID IF THE UNIT SHOWS EVIDENCE OF HAVING BEEN TAMPERED WITH, OR OPENED FOR OTHER THAN EITHER °C/°F OR MODEL 660 THERMOCOUPLE SELECTION.

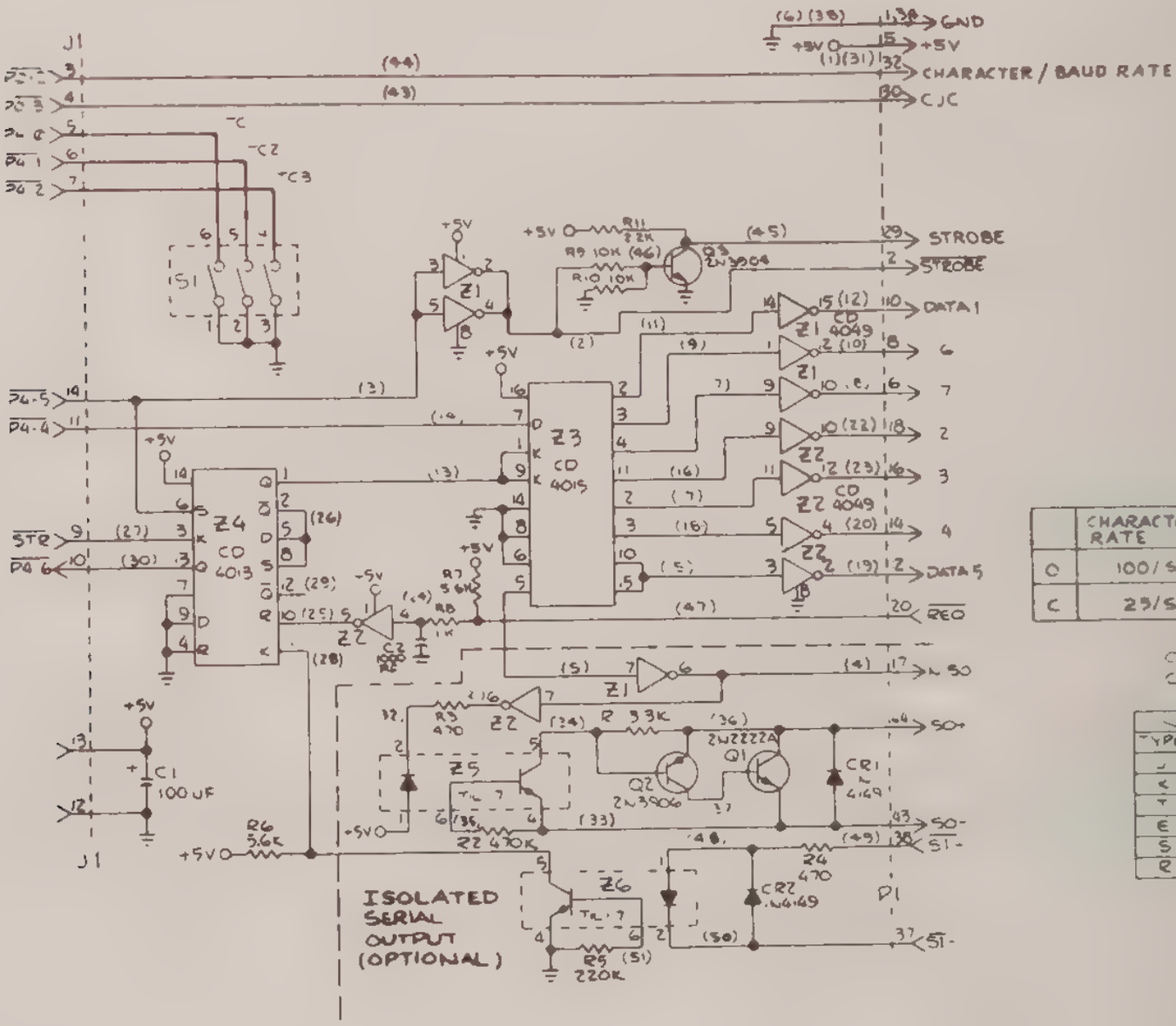
Any corrective maintenance required after the warranty period should be performed by qualified technical personnel only.


T1
W1
W2
VD
DC PWR OPTION
Q17 TIP31
Q1 LM330T
CR1
CR2
CR3
CR4
1N4001
C1 470
C2 220
C9 47
Z10 CD 4049B
C4 100 10V
CR4 1N4149
CR5 1N4149
C15 100 10V
N2 100K
A1 308
R5 560
C10 100PF
C16 0.1
C8 0.1
R4 270K
CR13 1N4149
CR8 1N4149
CR9
Z5 4016
CR 1N4145
R6 549K
C7 .12
A6 308
C7 .022
CR22 1N695A
R29
R7 100
A4 LM393
N2 100K
Z1 3870
EXT INT
RESET
EXTENDER
P1
PORT 5
PORT 0
Z3 CA 3081
N3
J1
J2
S1
Q5 MPSA13
Q6 MPSA13
Q7 MPSA13
Q8 MPSA13
DS1 MAN6630
DS2 MAN6660
DS3 MAN6660
DISPLAY BOARD
DIGITAL OUTPUT BOARD
REF
J1 REF
METER BD
DISPLAY
Q10 2N3905
R15
R17 100K
R9 22K
R8 10.2K
R21 16K
Q11 1403
R22 140K
R 500
R23 100
R25 56M
R24 56M
R27 68K
R26 68K
TC+
TC-
Z2 CD 4052B
C5 0.1
Q9 2N3906
C4 10
CR10 1N4149
A4 LM393
R2 5K
R13 2K
Z4 AD7543
A3 308
A2 308
R11 5K
R12 5K
R3 200
C12 100PF
ANALOG OUTPUT
ANALOG GND
ANALOG OUTPUT OPTION
*Q10 AND R15 ARE A SELECTED PAIR

MODEL 650 SCHEMATIC



MODEL 650
DIGITAL OUTPUT
BOARD

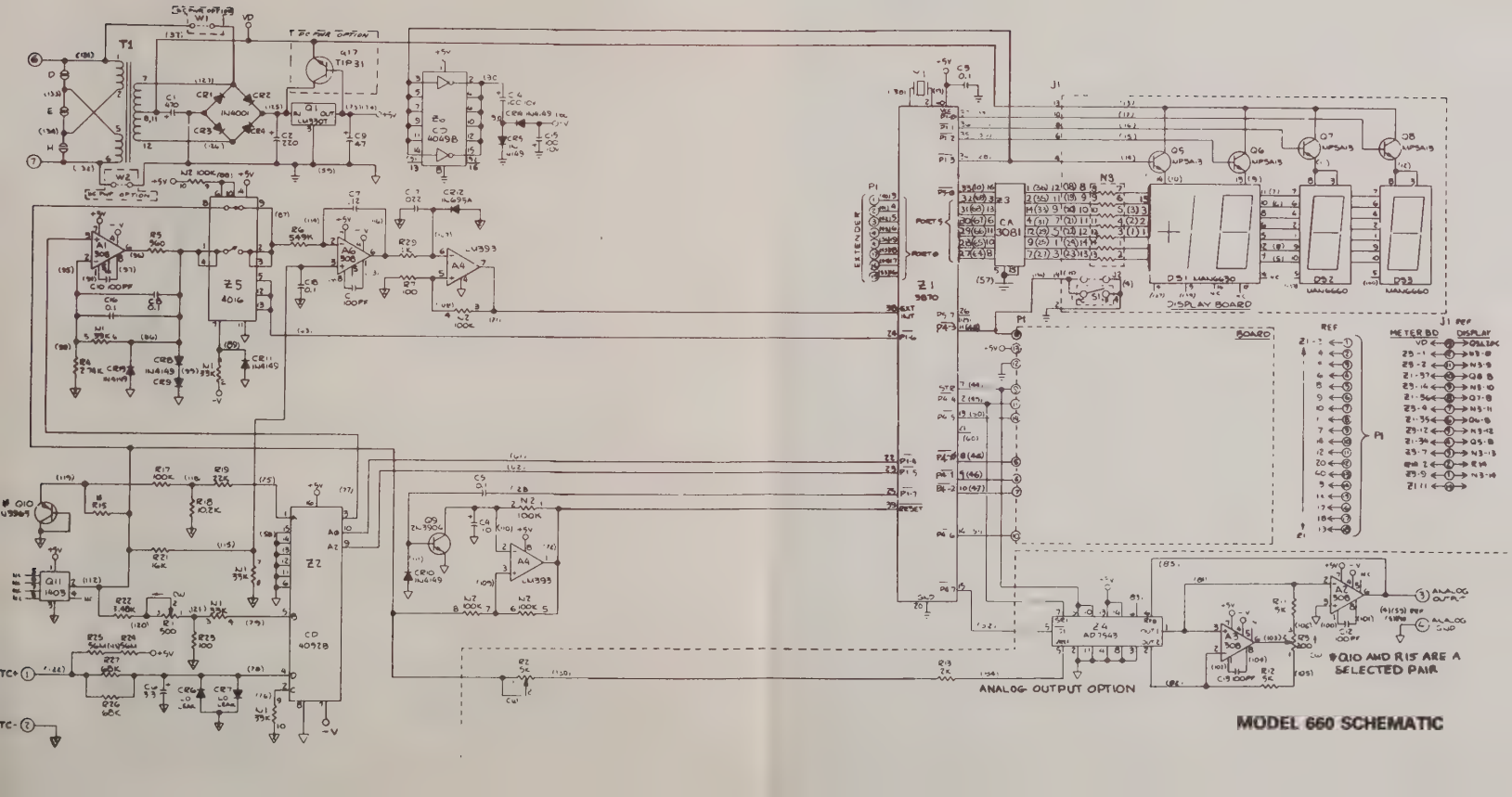


	CHARACTER RATE	BAUD RATE
O	100/SEC	1200/SEC
C	25/SEC	300/SEC

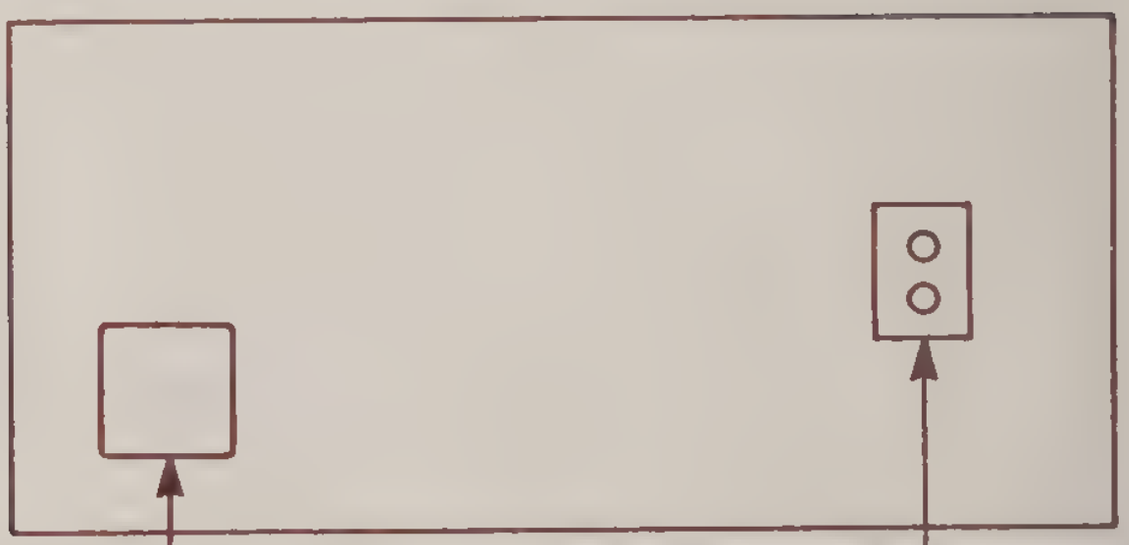
O: OPEN
C: CLOSED

	SWITCH POSITION		
TYPE	TC 3	TC 2	TC 1
J	O	O	O
K	O	O	C
T	O	C	O
E	O	C	C
S	C	O	O
R	C	O	C

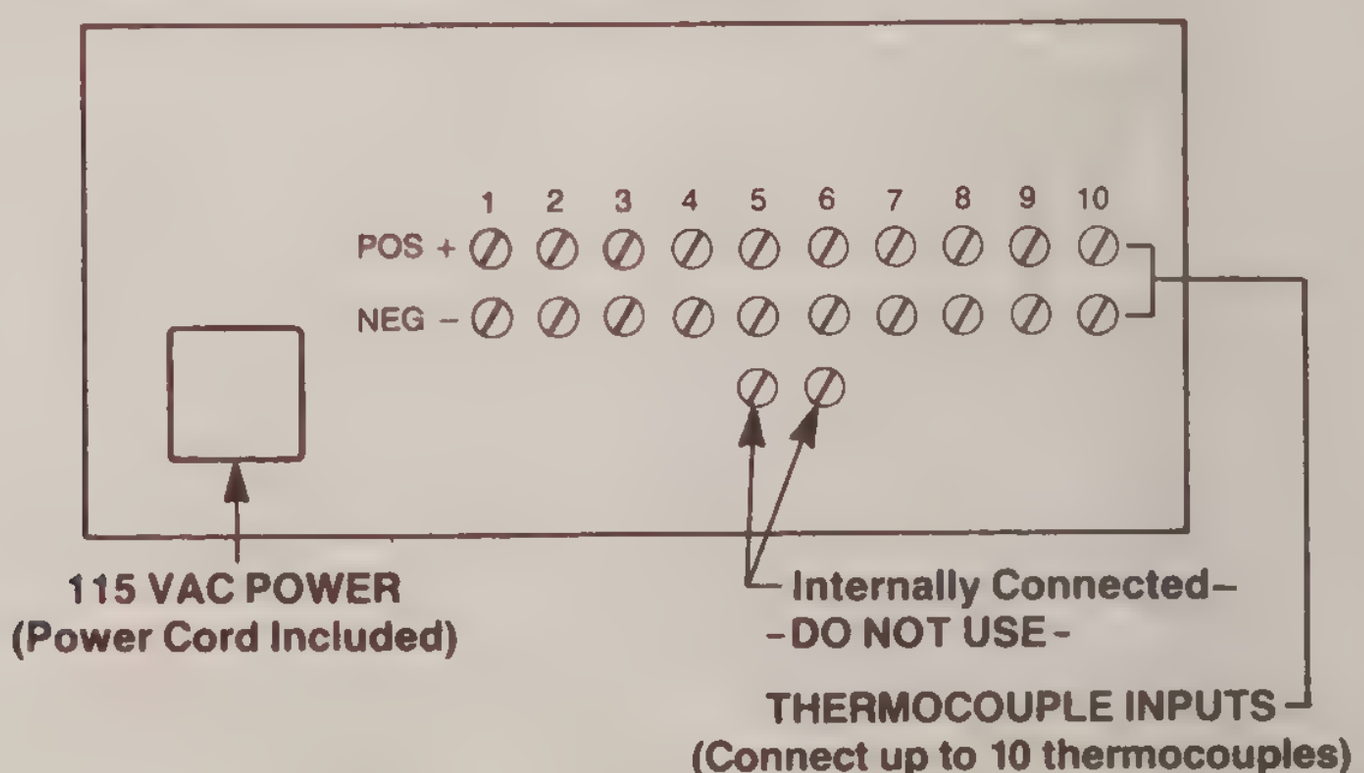
MODEL 660
DIGITAL OUTPUT
BOARD

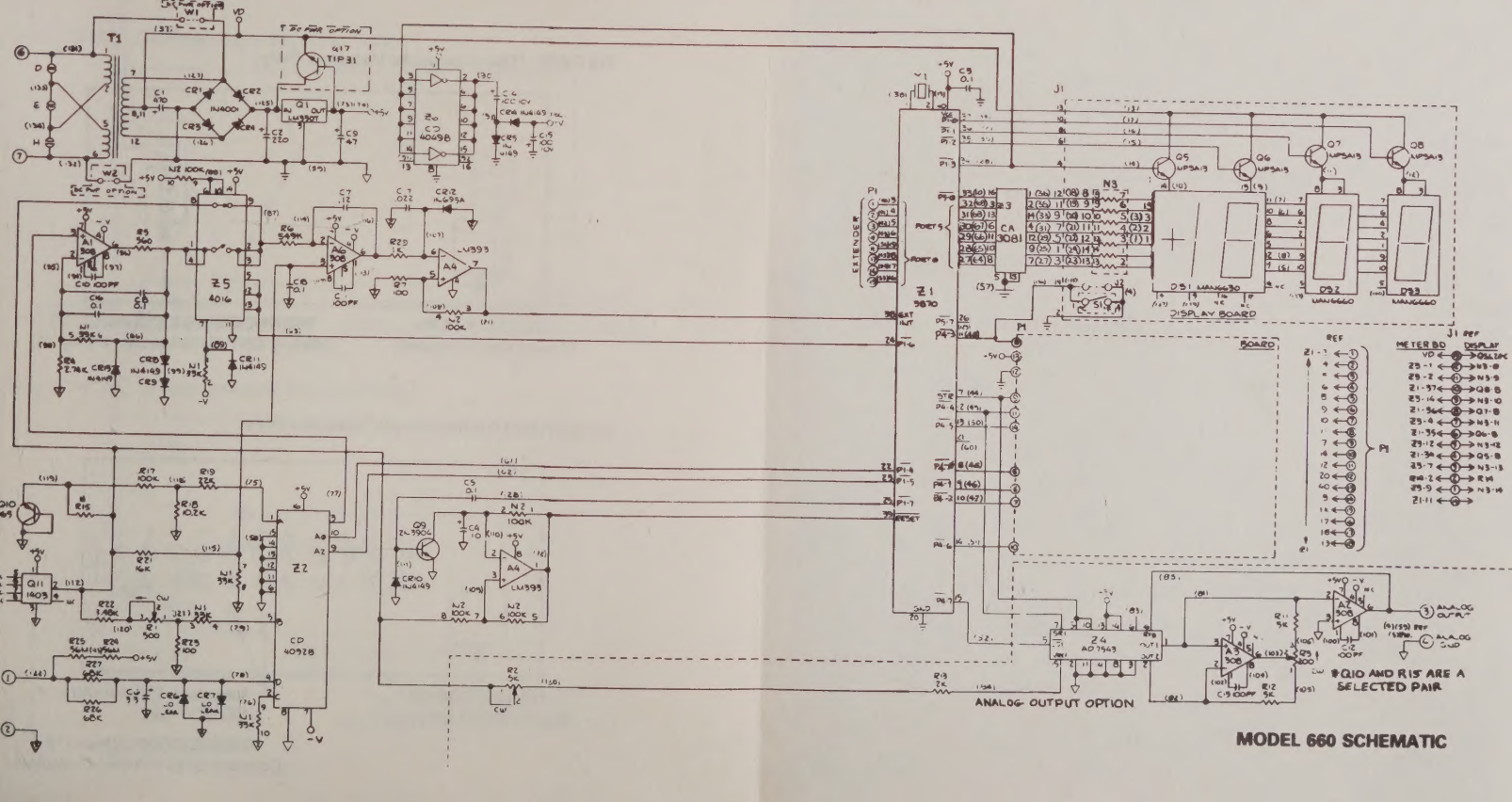

T1
TIP31
LM7805T
LM340T
8038
LM329
LM395
LM393
LM336
LM4040
4016
4066
4028
9370
9081
AD7549
LM4660
DISPLAY BOARD
ANALOG OUTPUT OPTION
ANALOG OUTPUT
ANALOG GND
* Q10 AND R15 ARE A SELECTED PAIR
MODEL 660 SCHEMATIC

DS CASE (Thermocouple Versions Only)

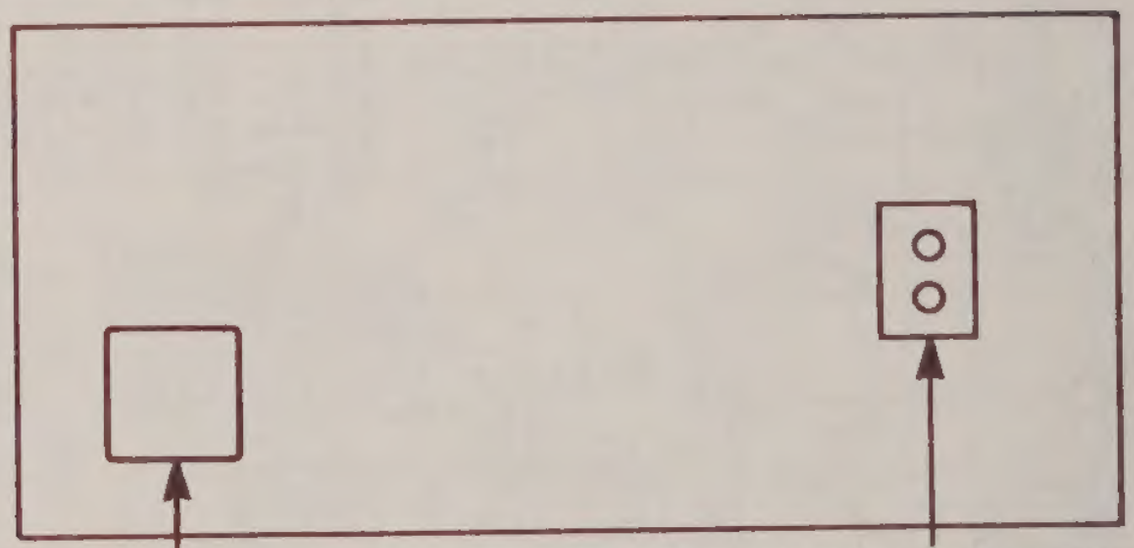


DSS CASE (Thermocouple Versions Only)




T1
Z1
3870
Z2
CD 40928
Z4
AD7543
Z5
4016
Z0
CD 4069B
CA 3081
DS1 MAN6630
DS2 MAN6660
DS3 MAN6660
215PLAY BOARD
EXTENDER
ANALOG OUTPUT OPTION
#Q10 AND R15 ARE A SELECTED PAIR
MODEL 660 SCHEMATIC

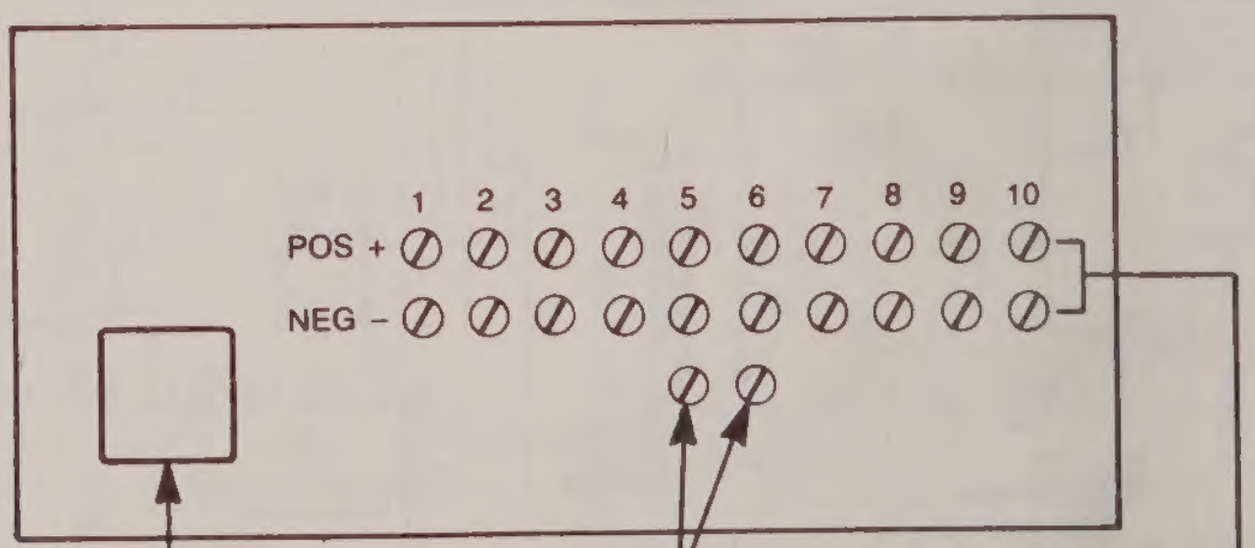
DS CASE (Thermocouple Versions Only)



115 VAC POWER
(Power Cord Included)

THERMOCOUPLE CONNECTOR
(Mating OST-M Connector included)

DSS CASE (Thermocouple Versions Only)

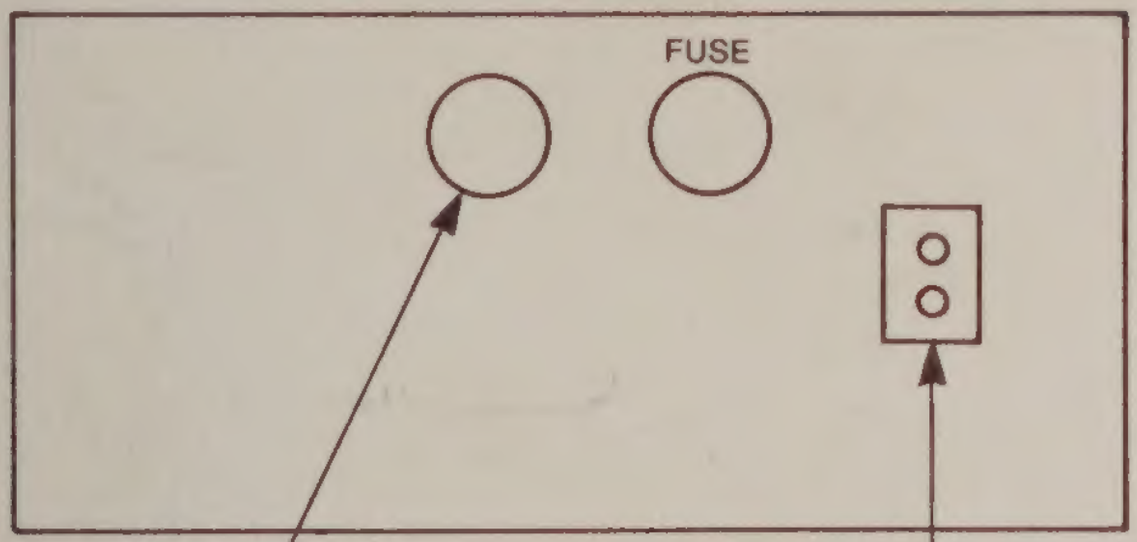


115 VAC POWER
(Power Cord Included)

Internally Connected–
–DO NOT USE–

THERMOCOUPLE INPUTS
(Connect up to 10 thermocouples)

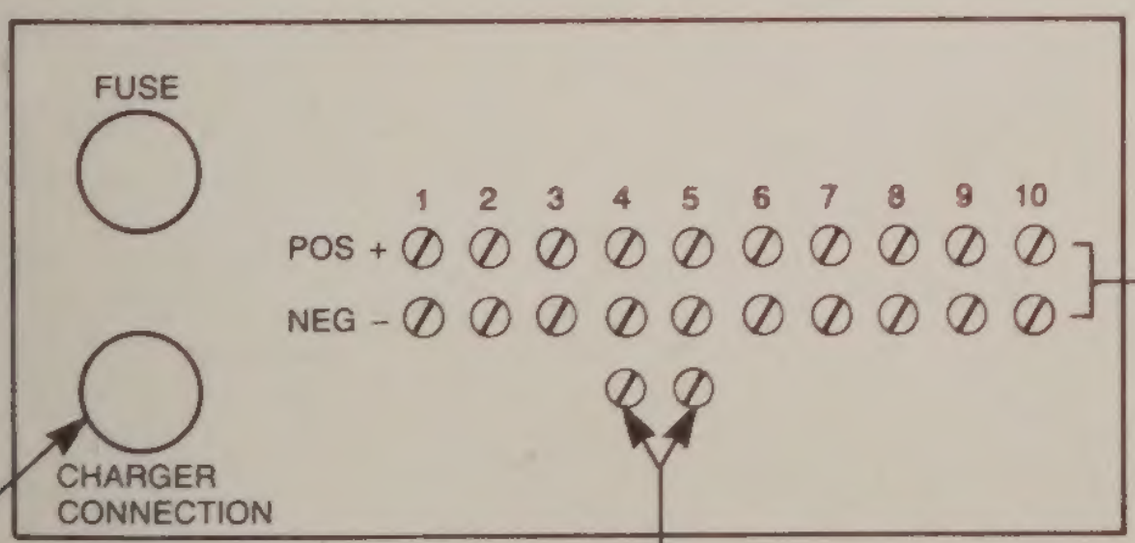
DS-01 CASE (Thermocouple Versions Only)



Charger Connection
(115/230 Charger Included)

THERMOCOUPLE CONNECTOR
(Mating OST-M Connector included)

DSS-01 CASE (Thermocouple Versions Only)



115/230 VAC
(Charger Included)

Internally Connected–
–DO NOT USE–

THERMOCOUPLE INPUTS
(Connect up to 10 thermocouples)

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- ☐ Recorders, Controllers and Process Monitors
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- ☐ Computer Sensor Interface

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- ☐ Transducers
- ☐ Strain Gauges
- ☐ Load Cells
- ☐ Pressure Gauges
- ☐ Instrumentation

FLOW

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- ☐ Flowmeter Systems
- ☐ Air Velocity Indicators
- ☐ Turbine/Paddlewheel Systems
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pH

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- ☐ Transmitters

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